Marine Fisheries REVIEW

Vol. 59, No. 4
1997
United States Department of Commerce

Mackerel

Marine Fisheries REVIEW

W. L. Hobart, Editor
J. A. Strader, Managing Editor

On the cover: The Pacific or chub mackerel, *Scomber japonicus.*

Articles *59(4), 1997*

Departments

U.S. DEPARTMENT OF COMMERCE
William M. Daley, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
D. James Baker, Under Secretary for Oceans and Atmosphere

National Marine Fisheries Service
Rolland A. Schmitten, Assistant Administrator for Fisheries

The *Marine Fisheries Review* (ISSN 0090-1830) is published quarterly by the Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., BIN C15700, Seattle, WA 98115. Annual subscriptions are sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402: The annual subscription price is \$10.00 domestic, \$12.50 foreign. For new subscriptions write: New Orders, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954.

Publication of material from sources outside the NMFS is not an endorsement, and the NMFS is not responsible for the accuracy of facts, views, or opinions of the sources. The Secretary of Commerce has determined that the publication of this periodical is necessary for the transaction of public business required by law of this Department. Use of the funds for printing this periodical has been approved by the Director of the Office of Management and Budget.

The NMFS does not approve, recommend, or endorse any proprietary product or proprietary material mentioned in this publication. No reference shall be made to the NMFS, or to this publication furnished by the NMFS, in any advertising or sales promotion which would indicate or imply that the NMFS approves, recommends, or endorses any proprietary product or proprietary material mentioned herein, or which has as its purpose an intent to cause directly or indirectly the advertised product to be used or purchased because of this NMFS publication. Periodicals postage is paid in Seattle, Wash., and at additional mailing offices. POSTMASTER: Send address changes for subscriptions for this journal to: *Marine Fisheries Review*, c/o Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. This issue, volume 59 number 4, was printed and distributed in August 1998.

An Assessment of Fishery Yields from the East China Sea Ecosystem

W. Z. CHEN, Y. Z. ZHENG, Y. Q. CHEN, and C. P. MATHEWS

Introduction

The East China Sea (ECS) (Fig. 1) supports some of the most important fisheries and stocks of the People's Republic of China (PRC) which are exploited by fishing fleets based in Zhejiang, Fujian, Jianxu, and Shanghai Provinces. PRC landings were 1,228,638 t (44.2% of total ECS landings), 1,042,233 t (37.5%), 379,403 t (13.6%), and 131,476 t (4.7%), respectively, for these four provinces, and totalled 2,781,750 t in 1992. The ECS landings also represented 27.8% of total PRC marine landings (9,336,927 t in 1992; China Ministry of Agriculture, 1993).

W. Z. Chen, Y. Z. Zheng, and Y. Q. Chen are with the East China Sea Fisheries Research Institute, 300 Jun Gong Road, Shanghai 200090, PRC; C. P. Mathews (corresponding author) is with the Zoology Department, University of Reading, UK. Present address: Northfield House, Cheselbourne, Near Dorchester, Dorset, DT2 7NT, UK, e-mail: 106337.760@compuserve.com. This paper is adapted from a paper by Chen and Shen (1995). Views or opinions expressed or implied are those of the authors and do not necessarily reflect the position of the National Marine Fisheries Service, NOAA.

ABSTRACT—A first assessment of important East China Sea fisheries was carried out using data from 1956 to 1993. Two different data sets were available: 1) catch and effort data taken from landings and boat registrations and 2) catch and effort data from skipper's logs taken at sea. The two sets provided similar trends in CPUE over the study period. Stocks of high value, low volume species have been fished heavily and now produce very low landings or have been depleted (e.g. small and large yellow croaker). Some high volume and low value species have also been heavily fished (e.g. green filefish) while others (e.g. hairtail) are still producing high landings. Surplus production models were fitted to seven stocks. All showed considerable fluctuations in landings around MSY. The green filefish stock had an estimated MSY of around 160,000 t/yr at an effort of 2,500,000 kw and was depleted by a combination of excessive effort (around 4,000,000 kw in 1993) and marked fluctuations in landings (up to 70,000 t/yr above or below MSY). A sustainable policy for managing ECS fisheries should address the effects of both effort and environmental variation.

Foreign landings in the ECS are not monitored. Recent estimates suggest that approximately 900,000 t/yr were landed in Taiwan, 400,000 t/yr in the Republic of Korea, and 200,000 t/yr in Japan by overseas fishing vessels operating in the ECS for a total foreign catch of 1,500,000 t/yr in the early 1990's.[1] Total ECS landings in 1992 were therefore about 4,200,000 t of which about 65% were landed by boats based in China. Although adequate data on foreign landings and effort are not available, it is important to carry out an assessment of the ECS landings and fisheries to identify a sustainable management policy for the area and its fisheries.

Methods and Data

Two data sets were available: 1) annual landings and effort data from fisheries statistics and 2) total catch, effort, and CPUE data from the offshore ECS Fishing Fleet logbooks.

Annual Landings and Effort Data

Annual landings and effort data are compiled by local, district, and Provincial Fisheries Management Bureaus (FMB's) and collated by the East China Sea Fisheries Management Bureau in Shanghai for the entire ECS. Effort is estimated from boat registration files and is measured in kilowatts. Effort estimates do not take into account the possibility that registered boats are unused, but it is thought that any biases will tend to be constant so that effort trends will be correctly estimated.

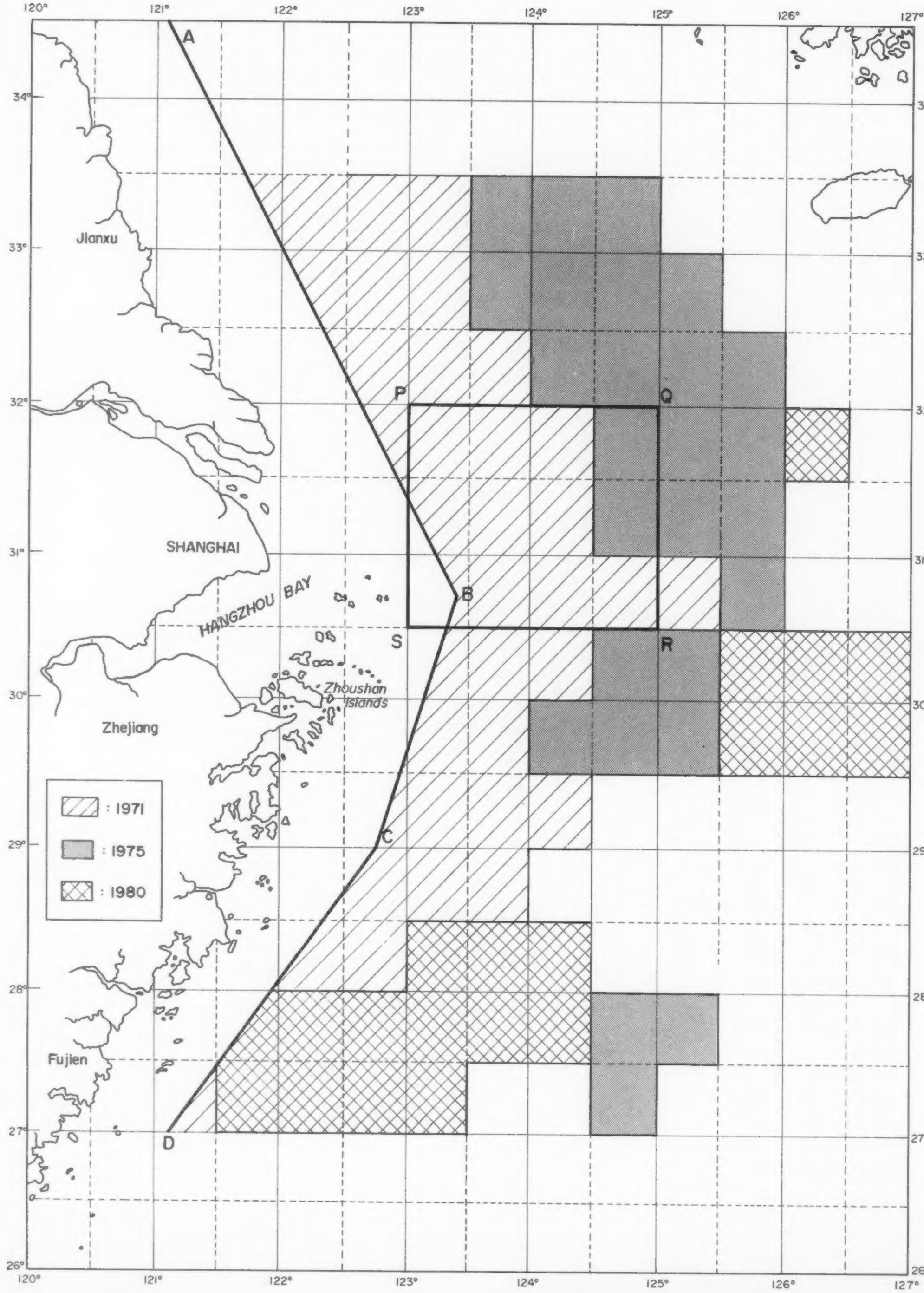
Until 1986, all fish landed were transported to large state-owned and managed fish processing plants where they were weighed and the species composition of the landings was recorded; data were reported to the FMB's. From about 1987 onward, a policy of economic liberalization was introduced, and fishermen were required to declare only the total value of landings by species. The volume of the landings was estimated at local FMB's by combining total value of the landings with price data. Total landings and effort data are made available about 12–18 months in arrears for the ECS as a whole. Landings data are only available by Province. Segregation of effort and landings data by smaller units is not possible at this time. Data on landings are available for the stocks listed in Table 1.

[1] East China Sea Fisheries Research Institute, Shanghai. Unpubl. rep.

Table 1. — East China Sea fish stocks[1] for which landings are available.

Common name	Scientific name
Large yellow croaker	*Pseudosciaena crocea*
Small yellow croaker	*Pseudosciaena polyactis*
Edible jellyfish	*Rhopilema esculenta*
Cuttlefish	*Sepiella mandroni*
Green filefish	*Navodon septentrionalis*
Hairtail	*Trichiurus haumela*
Mackerel and scad	*Scomber japonicus* and *Decapterus maruadsi*
Spanish mackerel	*Scomberomorus* sp.
Pomfrets	*Pampus argenteus, P. cinereus, P. sinensis*
Chinese herring	*Ilisha elongata*
Shrimp and crabs	>99% palaemonids and portunids

[1] In addition, data are available for a wide variety of low-valued, high-volume species grouped together as "other species" as defined in the text.



120°
121°
122°
123°
124°
125°
126°
127°
34°
33°
32°
31°
30°
29°
28°
27°
26°
A
B
C
D
P
Q
R
S
Jianxu
SHANGHAI
HANGZHOU BAY
Zhoushan Islands
Zhejiang
Fujien
: 1971
: 1975
: 1980

The three species of pomfrets may reasonably be treated as a unit stock, as may all of the others excepting mackerel and scad (7) and shrimp and crabs (11) (Table 1), which are multispecies stocks. No records are available of their varying species composition.

No data are available on the allocation of effort between stocks, which are fished by means of a wide variety of pelagic, semipelagic, and demersal gears. To allow a first assessment of important ECS stocks, the relation between landings for the above stocks and total ECS effort was studied using various Shaeffer (1957), Pella and Tomlinson (1969), and Fox (1970) models, fitted with CLIMPROD (FAO, 1994) and POPDYN (hall, 1986). This procedure arbitrarily assumes that a constant proportion of total ECS effort was allocated to each stock from 1956 to 1993. This assumption will be violated when a stock is driven to extinction (<5% of peak landings). The assumption will also be erroneous during the first few years of a fishery when a new stock is attracting effort, but in practice this was not a problem as data for most stocks were only collected for periods during which the stock produced landings >5% of peak landings; extrapolations were carried out where necessary.

Total Catch, Effort, and CPUE Data

From 1971 to 1982, data on total effort and CPUE were collected manually for the offshore fishing fleet (operating east of line ABCD, Fig. 1) by the East China Sea Fisheries Research Institute, through skippers' log books, by half-degree squares. Data were computed annually. Using these data it was possible to:

1) Determine the spread of effort from the inshore area towards the east into the ECS,
2) Estimate total effort, catch per unit effort (CPUE), and fishing intensity by half-degree square, and
3) Estimate mean annual CPUE for the whole offshore ECS fishery only, allowing comparison with estimates of the CPUE for the whole ECS from fisheries statistics data collated by the East China Sea Fisheries Research Bureau (see previous section on annual landings and effort data).

◀ Figure 1. — The East China Sea: line ABCD separates the Coastal Management Zone (to the west), in which trawling is prohibited for all species (except beam trawling for shrimp), and the offshore area (east of ABCD). Small onshore boats (>25 GT and <125 GT) operate primarily in the onshore area (west of ABCD) while the fleets of larger (150–650 GT) boats operate in the offshore zone only (east of ABCD). Fisheries assessment and management in both offshore and onshore areas are the shared responsibility of the East China Sea Fisheries Research Institute and the East China Sea Fisheries Management Bureau, and of the Zhejiang Provincial Fisheries Research Institute and the Zhejiang Fisheries Management Bureau. Area PQRS is typical of all similar areas adjacent to and east of line ABCD.

Results

ECS Fishing Gear Distribution

A wide variety of gears are used for fishing in the ECS (Fig. 2) where inshore fishing (mostly by boats >25 GT and <125 GT) is reserved for small gear and set net fishing. Offshore fishing is usually reserved for large-scale purse seining and trawling (usually 150–650 GT boats).

Expansion of the ECS Fishing Area, 1971–82

Figure 1 shows the movement of effort offshore from 1971 to 1980 in the ECS. By 1982, the last year for which the half-degree square data are available, effort had moved still further offshore. Prior to 1965 the ECS fishery was entirely coastal (i.e. west of ABCD, Fig. 1); by 1971 a substantial offshore area (51,000 n.mi.^{2}) had been occupied, and by 1982 most of the ECS out to long. 127° (97,000 n.mi.^{2}) was fished, albeit only lightly in the far eastern area. Table 2 shows in more detail how effort expanded and fishing intensity changed from 1974 to 1980. Fishing intensity was much higher in the western part of the offshore area PQRS (Fig. 1, characteristic of areas east of and adjacent to line ABCD), than in the ECS as a whole. Effort in this area also increased at a much higher rate (×6.73) than in the ECS as a whole (×2.12).

Table 2. — Changes in ECS fishing strategy, 1974–82 (see Figure 2 for areas studied)

	Data for entire ECS		PQRS data only
Year	Total effort (h/yr)	Fishing intensity (h/n.mi.^{2})	Fishing intensity (h/n.mi^2)
1974	123,279	1.90	2.20
1975	142,273	1.94	3.53
1976	204,498	2.84	6.00
1980	386,943	4.03	15.42
Ratio[1]	3.14:1	2.12:1	6.73:1

[1] Ratio for 1989:1974.

Calibration of CPUE

CPUE was estimated independently for the whole ECS from fisheries statistics recorded in the aforementioned data set 1 (annual landings and effort data), with CPUE measured in t/kw, and from data set 2 (CPUE data) recorded in skipper's logbooks during fishing, with CPUE in mean t/h of fishing for 6 years (1971, 1974, 1975–76, 1980, 1982). The least squares regression of CPUE estimated in t/kw (for the whole ECS from fisheries statistics) on CPUE estimated in t/h (for the offshore ECS only, east of line ABCD, Fig. 1) was significant ($r = 0.962$, $p = 0.002$); the intercept was not significantly different from 0 ($p < 0.05$). From 1971 to 1982, the offshore fishery caught mainly green filefish, mackerel and scad, and hairtail, whereas the whole ECS landings included these species and other large important stocks such as shrimp and crab, large yellow croaker, "other species,"[2] pomfret, and cuttlefish, taken mainly to the west of line ABCD (Fig. 1). The significant correlation of CPUE's suggests that trends in CPUE are similar for all stocks, and supports the simplifications needed to assess the ECS fish stocks.

Changes in Landings

ECS landings may be divided into 1) small volume and relatively high value "old" species fished since 1956, 2) high volume, relatively low value "new" species fished heavily mainly from around 1965 onwards, and 3) a variety of very low value "other" species used for aquaculture feed, reduction to fish meal, and only occasionally for human con-

[2] See following "Changes in Landings" section for the definition of this term.

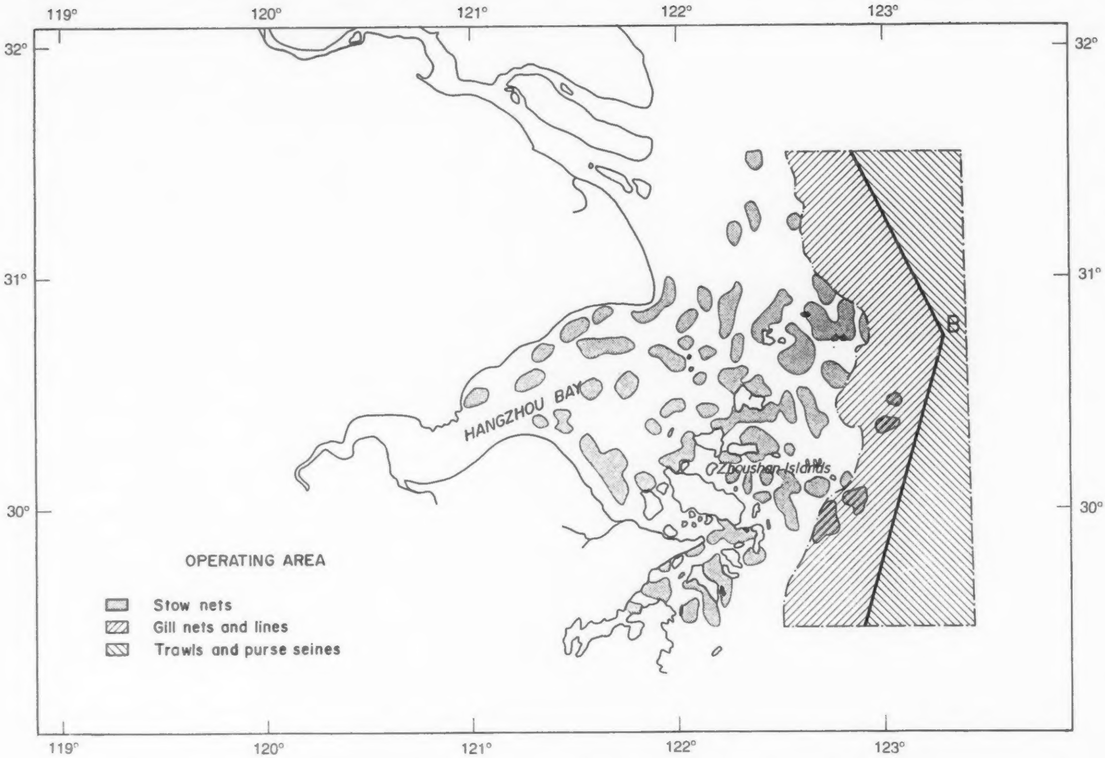


Figure 2. — Distribution of marine fishing gear in the ECS near Hangzhou Bay. Point B is also shown in Figure 1. The offshore fleet uses mostly trawls and purse seines. The inshore fleets use smaller boats and more artisanal, small-scale, gear.

sumption. The volume of "old" species landed fell from >300,000 t in 1956 to about 50,000 t in 1992, while the volume of "new" species rose from 250,000 t in 1956 to >1,000,000 t in 1992 (Fig. 3). Landings of all old species except Chinese herring fell markedly (Fig. 4); landings of three new species increased markedly (hairtail, 100,000–650,000 t/yr; shrimp and crab, 132,000–550,000 t/yr; mackerel and scad, <200–300,000 t/yr; from 1956 to 1993, respectively; Fig. 5). Three new fisheries (pomfrets, Spanish mackerel, and green filefish) were established in the 1970's, while the mackerel and scad stock was more heavily fished. Of the 11 stocks for which data are available, five showed a marked long-term fall in landings. Large yellow croaker, small yellow croaker, jellyfish, cuttlefish, and green filefish were fished so heavily that the stocks were all reduced to commercial insignificance by 1990. Data for cuttlefish (Fig. 4) do not show this clearly because *S. mandroni* (the main species providing >95% of the cuttlefish landings) was fished in inshore and western ECS waters, but was replaced by various offshore species from about 1985 onwards. The proportion of *S. mandroni* in the landings was not monitored regularly, but it is known to have fallen to very low levels (<10%) by 1993.

Surplus Production Modelling

Results of surplus production modelling are shown for eight different stocks (Fig. 6, 7; Table 3), most of which showed decreasing landings at higher effort levels. The green filefish stock (Fig. 6) was commercially extinguished in the early 1990's when landings fell to about 3,000 t/yr and effort exceeded 4,000,000 kw. Landings of yellow filefish, *Thamocomus modestus*,

Table 3. — Results[1] of surplus production modelling of important ECS stocks.

Species	MSY (t)	F_{opt} (kw)	R^2 (%)
Large yellow croaker	120,000	500,000	79
Small yellow croaker	40,000	300,000	68
Jellyfish	25,000	600,000	56
Cuttlefish	50,000	500,000	84
Green filefish	160,000	2,500,000	57
Pomfrets	50,000	3,500,000	61
Hairtail	420,000	2,000,000	71
Chinese herring	20,000	50,000	68

[1] MSY = maximum sustainable yield, nearest 5,000 t/yr; F_{opt} = Effort needed to harvest MSY, nearest 50,000 kw.

increased from traces (<1%) prior to about 1990 to 30,000–40,000 t in 1993 as this offshore stock was fished to replace the lost green filefish landings. Green filefish reach 35 cm total length (TL), and in the mid 1980's the modal size of fish landed was about 25 cm TL; yellow filefish are smaller (up to 20 cm TL, modal size about 15 cm TL), and are less valuable. Only the promfrets

stock supported increasing landings for the effort range studied. Hairtail landings showed a decreasing trend with increasing effort until about 1990 (effort >3,000,000 kw). Models could not be fitted for mackerel and scad, Spanish mackerel, and shrimp and crab because these stocks show continuously increasing landings (Fig. 5).

Discussion

Effects of Increasing Effort

Total ECS landings show a continuously increasing trend, but five important stocks (with combined peak landings of about 650,000 t/yr) have been fished to commercial extinction from about 1979 to 1990, while only three important stocks show an increasing trend. Of these, shrimp and crab are a multispecies multigear stock, with (according to anecdotal reports) a sharp increase in number of species fished, with several new types of gear, especially in the Zhoushan Islands in the last 5 years. This stock is probably similar to ECS fisheries as a whole, with overfished species being replaced as effort increases, by new and previously unfished, or markedly underfished, species. Because data are lacking it is not possible to assess how this stock will react to future effort increases.

The mackerel and scad stock is more homogeneous but the proportion of the species in the landings is not known and may have changed in response to increasing effort. Only the promfrets stock shows stable landings, while only the Spanish mackerel stock (and some components of the multispecies shrimp and crab stock) may not be fully fished. Increasing landings of the "other species" stock offers the possibility of maintaining landings for human consumption in spite of the generally decreasing trends in landings for important fisheries (but only if methods for generally processing fish currently rejected as food for human consumption can be identified and applied at an industrial scale as was done for filefish in the 1970's, stimulating development of the fishery).

Detailed trophic studies of ECS fish stocks have not yet been completed, but large and small yellow croaker are known to be secondary predators, and have been replaced in the landings by primary predators (e.g. hairtail and, until recently, green filefish).

Projection of total ECS effort, based on observed effort expansion from 1956 to 1993, suggests that by 2013, total effort will have increased from about 4,000,000 kw to around 14,000,000 kw.

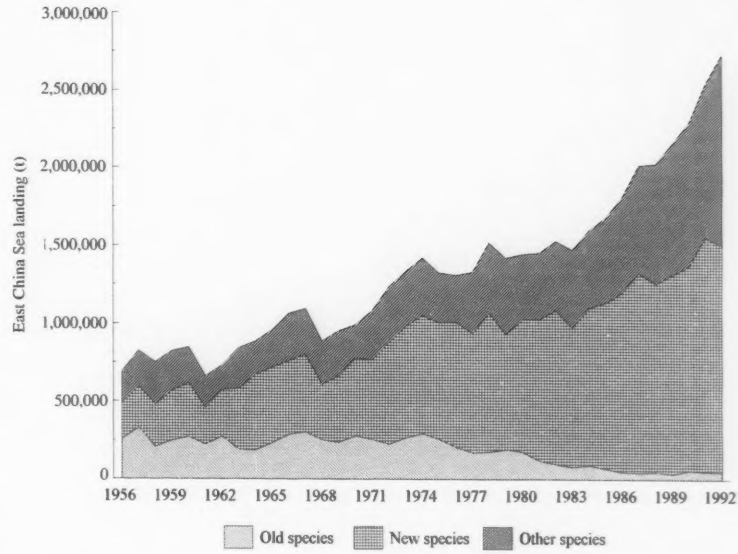


Figure 3. — East China Sea landings separated into "old," "new," and "other" species.

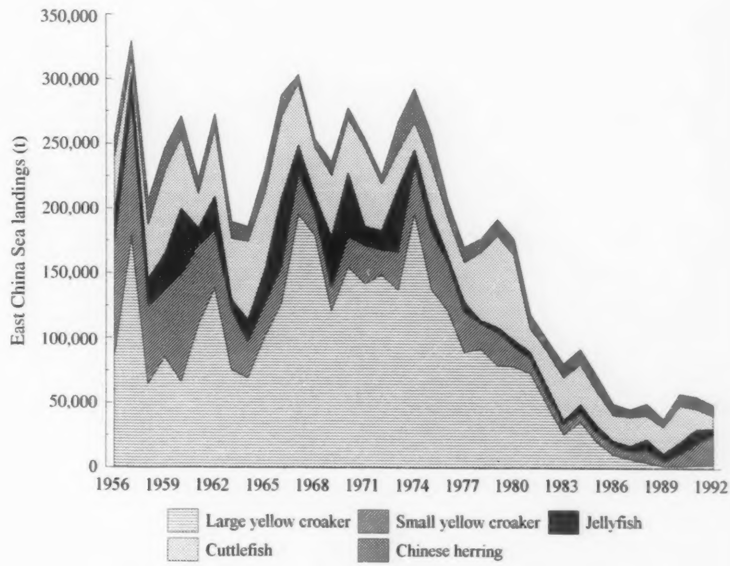


Figure 4. — Landings of "old," relatively highly priced, species.

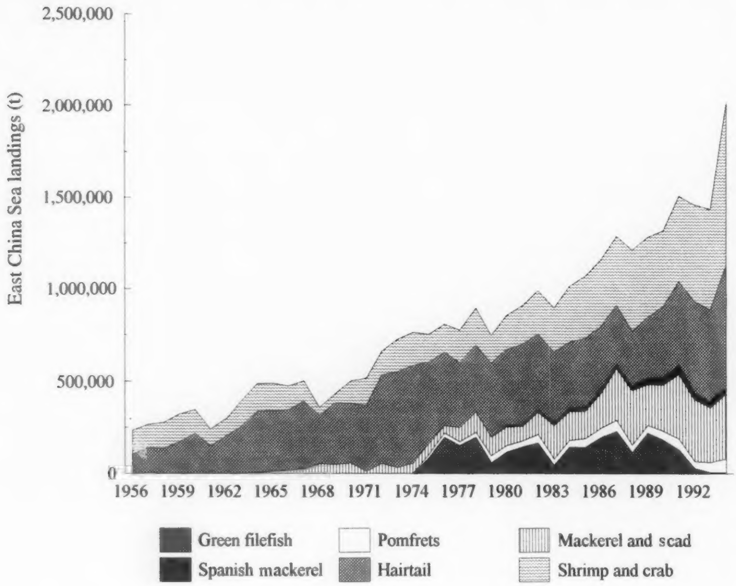


Figure 5. — Landings of "new," relatively low priced, species.

It is very unlikely that this rate of effort expansion is sustainable: either an effort limitation policy will be devised and implemented and will lead to a sustainable level of harvest for some of the remaining stocks, or effort will eventually be reduced as a response to falling catch rates and profitability, with consequent economic losses in the fishing sector as a whole when this eventually occurs.

Fluctuations in Landings

Figures 5–7 all show that sustainable short-term fluctuations in landings may occur around a generally sustainable level of landings. In the case of green filefish, landings fluctuated by >70,000 t annually around an MSY of 160,000 t (Fig. 6). These fluctuations were probably caused by changes in environmental factors. This instability, combined with rapidly expanding effort (about 25% from 1988 to 1993) may have contributed to the commercial extinction of the green filefish stock. On the other

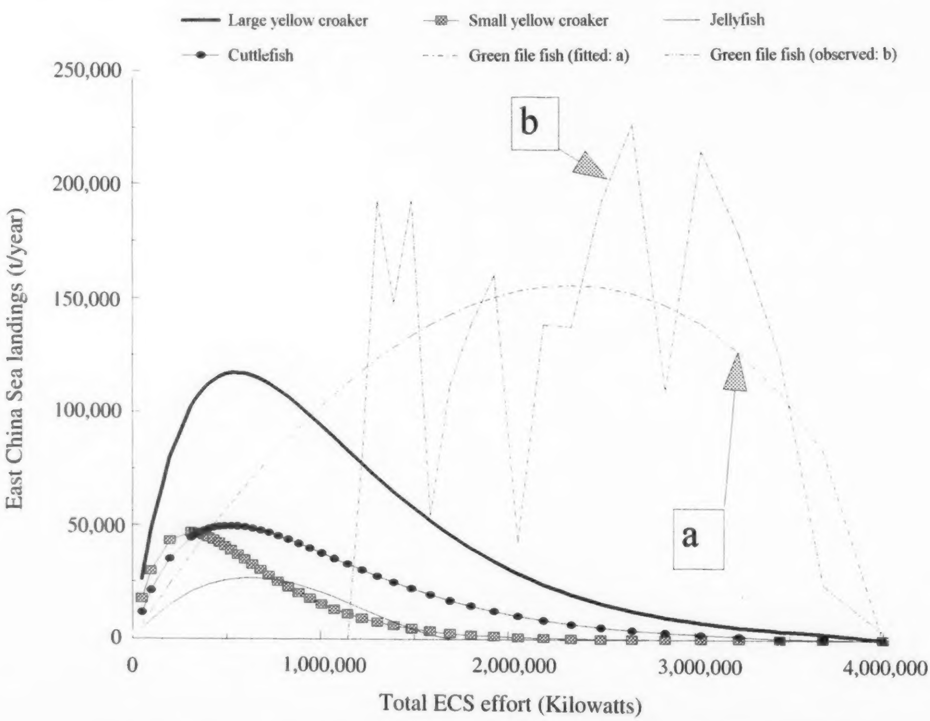


Figure 6 .— Surplus production models for five stocks that have showed decreasing landings.

hand, hairtail landings (Fig. 7) increased in the early 1990's in spite of a decreasing trend over the previous decade, but recent landings were dominated by immature 1-year-old fish. Landings of small yellow croaker showed a sharp increase from <3,500 t in 1989 to >23,000 t in 1992 (Fig. 4), but were dominated by 1–2 year old fish 12–15 cm TL, instead of the larger (20 cm TL) older (3–5 year olds) that previously dominated the landings. Minimum size at maturity for this species has decreased from 14–15 cm TL in the 1970's to around 11–12 cm TL in the 1990's, consistent with heavy overfishing. Increases in landings of hairtail and large yellow croaker in the 1990's may also have been caused by environmental variation. This possibility causes concern: when the environmental influence is reversed, landings of hairtail may fall below the level shown by the fitted curve (Fig. 7), while landings of small yellow croaker may return to levels characteristic of the late 1980's. Even well established fisheries such as hairtail are now vulnerable to overfishing, while any increase in the landings of overfished species is likely to be temporary. A sustainable exploitation policy for the ECS fisheries should address the effects of both environmental variation and increasing effort.

Acknowledgments

Work reported here was carried out on the Hangzhou Bay Project and was supported by the World Bank and the National Environmental Protection Agency and of the People's Republic of China. Support was also given by the Zhejiang Environmental Protection Agency and the Shanghai Environmental Agency.

Literature Cited

Chen Y., and Z. Shen. 1995. Changes in the biomass of the East China Sea ecosystem. *In* Q. Tang and K. Sherman (Editors), The large marine ecosystems of the Pacific Rim, p. 91–112. IUCN, Gland, Switzerland.

China Ministry of Agriculture. 1993. China fisheries statistics, 1993. China Minist. Agric., Beijing.

FAO. 1994. CLIMPROD: experimental interactive software for choosing models including environmental variables. Food Agric. Organ. U.N., Rome, 126 p.

Fox, W. W. 1970. An exponential yield model for optimizing exploited fish populations. Trans. Am. Fish. Soc. 99:80–88.

Hall, N. 1986. Population dynamics programmes for the programmable computer. Kuwait Inst. Sci. Res., Kuwait Rep., p. 1–15.

Pella, J. J., and P. K. Tomlinson. 1969. A generalized stock production model. Inter-Am. Trop. Tuna Comm. Bull. 13:419–496.

Shaeffer, M. B. 1957. A study of the dynamics of the fishery for yellowfin tuna in the eastern tropical Pacific Ocean. Inter.-Am. Trop. Tuna Comm. Bull. 2:247–268.

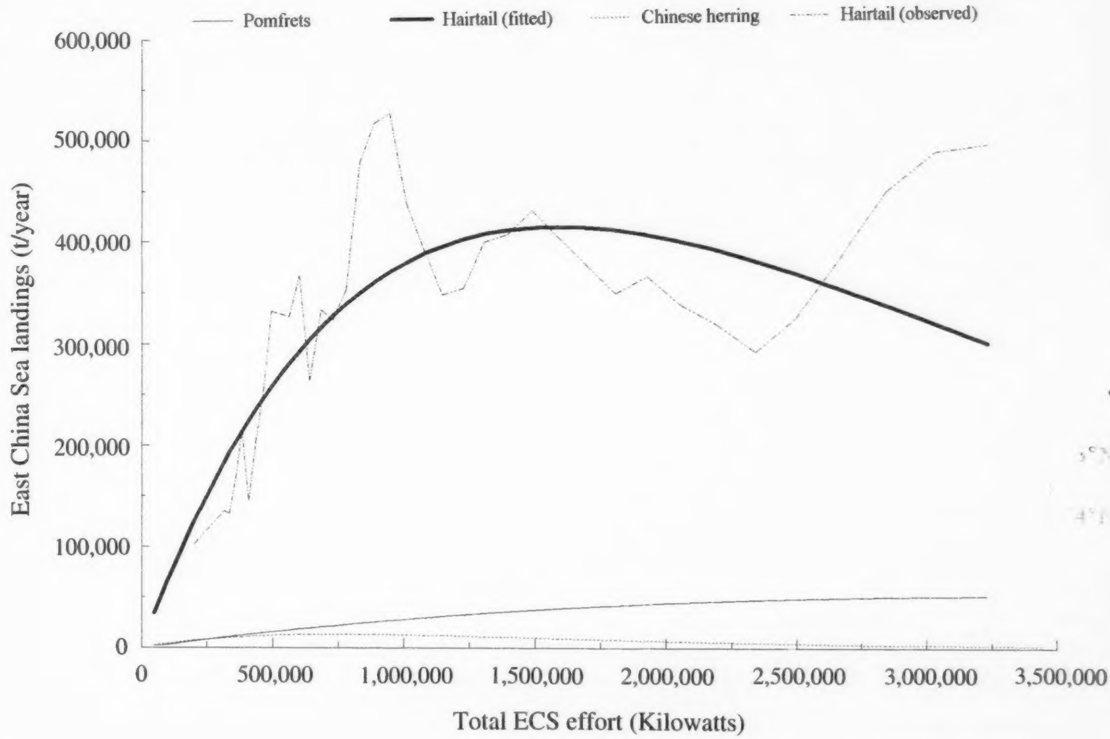


Figure 7. — Surplus production models for three species showing increasing (hairtail, Chinese herring) and sustained (pomfrets) landings.

Stocking, Enhancement, and Mariculture of *Penaeus orientalis* and Other Species in Shanghai and Zhejiang Provinces, China

J. XU, M. XIA, X. NING, and C. P. MATHEWS

Introduction

Fish as a Source of Food

Marine and freshwater landings from capture and culture fisheries in the People's Republic of China (PRC) have steadily increased since 1982 (Fig. 1A). In 1991 the combined landings of >21,000,000 t were dominated by capture landings (61.9%). Per-capita consumption of fish of all kinds in the PRC was 18.1 kg/yr in 1991, with 6.9 kg/yr from culture and 11.2 kg/yr from capture fisheries. Landings from mariculture in 1991 provided the smallest contribution: only 3.2 kg/yr (17.9% of total landings).

J. Xu and M. Xia are with the Zhejiang Marine Fisheries Research Institute, Shenjiamen, Zhoushan, People's Republic of China; X. Ning is with the Second Institute of Oceanography, P.O. Box 1207, Hangzhou, Zhejiang 310012, PRC, and C. P. Mathews (corresponding author) is with the Zoology Department, University of Reading, Whiteknights, Reading, England. His present address is Northfield House, Chesel-bourne, Dorset, DT2 7NT, England. Internet: 106337.760@compuserve.com. Views or opinions expressed or implied are those of the authors and do not necessarily reflect the position of the National Marine Fisheries Service, NOAA.

ABSTRACT—China's marine aquaculture landings provide only 18% of its combined freshwater and marine capture and culture landings, at a per-capita consumption of only 3.2 kg/yr out of a total of 18.1 kg/yr. We described development and some of the results of long-term mariculture and stocking/enhancement projects that have been underway for up to 20 years in the Hangzhou Bay area. Penaeus orientalis *(also referred to as* P. chinensis*) stocking provided up to 400 t/yr, at a total cost-benefit ratio of up to 8 Yuan of landed shrimp per Yuan invested in shrimp stocking. Over 40 t of* Penaeus orientalis *were produced commercially in 1993, with proceeds being used to fund mariculture and fisheries research. Large-scale edible jellyfish restocking is also underway, while semicommercial culture of abalone,* Haliotis diversicolor, *has been successful. Technical problems limiting mariculture have been solved successfully for some species.*

Culture landings are dominated by freshwater fish (48.7%; Fig. 1A), mostly from small farms and aquaculture facilities. Mollusks and crustaceans (almost entirely marine) provide important contributions to culture landings (2.2% and 15.3%, respectively, Fig. 1B), while marine fish form a very small portion of the total (only 0.6%). Algae (>90% *Laminaria japonica*) provide 34.1% of culture landings, but are harvested directly, generally without any significant associated culture or farming activities. Table 1 provides a more detailed breakdown of culture landings by species.

Attempts at fisheries stocking and enhancement have been made in the PRC but have contributed only a negligible proportion of the landings. This paper describes results of attempts to increase landings by stocking shrimp, *Penaeus orientalis* (also referred to as *P. chinensis*), and enhancing jellyfish, *Rhopilema esculenta*, landings in Zhejiang Province, which landed >1,300,000 t from capture fisheries in 1991, compared to <40,000 t from mariculture landings.[1] Information is also provided about some of the mariculture activities in Zhejiang Province.

Table 1.—Aquaculture landings (1,000 t) by species in the PRC and in percent total culture landings, 1993 (FAO, 1994).

Species	Landings (1,000 t)	Percent of total
Freshwater fish		
Carassius carassius	254.3	2.4
Cirrhinus mulitorella	81.0	0.8
Ctenopharyngodon idella	1,231.8	11.8
Cyprinus carpio	706.1	6.8
Hypophthalmichthys molitrix	1,540.7	14.8
Hypophthalmichthys nobilis	770.4	7.4
Mylopharyngodon piceus	51.8	0.5
Parabramis pekinensis	181.5	1.7
Oreochromis (Tilapia) niloticus	157.2	1.5
Subtotal	4,974.9	47.8
Marine Fish, Subtotal	58.7	0.6
Marine Crustaceans		
Eriocheir sinensis	9.5	0.1
Penaeus chinensis	206.9	2.0
Other marine crustaceans	8.6	0.1
Subtotal	225.0	2.2
Marine mollusks		
Crassostrea gigas	123.0	1.2
Mytilidae	538.9	5.2
Pecten yessoensis	338.0	3.2
Anadara granosa	41.6	0.4
Solen spp	198.6	1.9
Venerupis japonica	270.5	2.6
Other mollusks	86.9	0.8
Subtotal	1,597.4	15.3
Algae		
Laminaria japonica	2,964.8	28.5
Porphyra tenera	159.0	1.5
Other algae	429.4	4.1
Subtotal	3,553.2	34.1
Grand Total	10,409.1	100.0

Study Area

The study area, located in the Zhoushan Islands, is situated in Hangzhou Bay, on the East China Sea (Fig. 2). Coastal waters are generally turbid and of low salinity (<25‰) in Hangzhou Bay and around the Zhoushan Islands, and show a temperature range of 4–11°C in February and 26–28°C in August (Ning,

[1] Unpublished data, East China Sea Fisheries Research Institute, Shanghai; Zhejiang Marine Fisheries Bureau, Hangzhou; Asian Development Bank, 1993 [unpubl. rep. on the Zhoushan Fisheries, 340 p.]

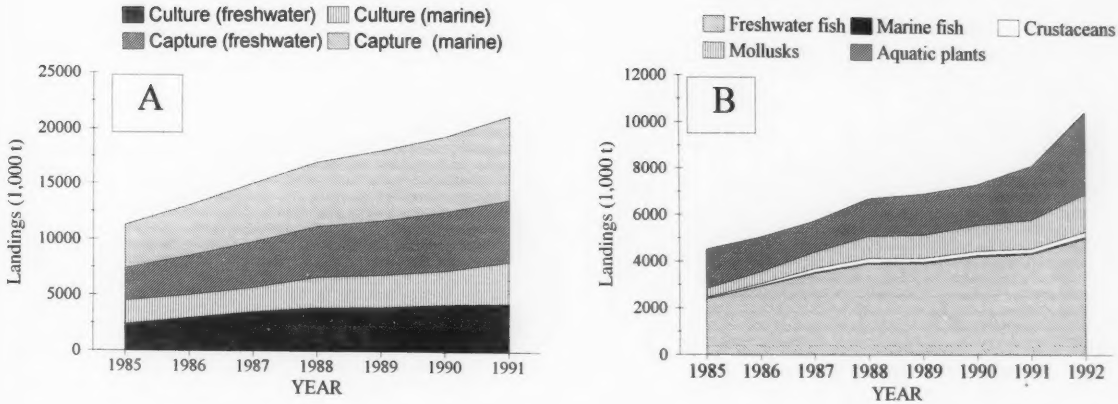


Figure 1. — A: People's Republic of China (PRC) culture and capture landings, 1985–91. Data from FAO (1992). B: Composition of PRC culture landings by general type, 1985–91. Data from FAO (1992).

1994). Oceanographic structures in Hangzhou Bay and the East China Sea are very complex, with water from the Changjiang (Yangtze) River, which has an inflow of >28,000 m^3/sec, providing an important and perhaps dominant influence in coastal waters. Smaller inflows come from the Qian Tang (1,100 m^3/sec), the Huangpoo (>300 m^3/sec), and other rivers entering Hangzhou Bay from the west such as the Casejiang and the Yongjiang (230 m^3/sec). Depending on the time of year, coastal waters in the study area are also influenced by the mixing of different water masses coming from the plume of the Changjiang and the Taiwan Warm Current, an inshore branch of the Kuroshio Current (Second Institute of Oceanography, unpubl. rep.). In summer, incursions of warm, clear, and salty Taiwan Warm Current water may move westwards from the East China Sea, bringing clearer, more transparent waters across the Zhoushan Archipelago and into Hangzhou Bay. These incursions may cause red tides in some years, impacting aquaculture activities. Red tides are probably related to nutrient flows into the study area from the Changjiang River basin, and to agricultural and industrial pollutants entering the study area from the west. A full description of the study area and its characteristics is given in ADB[2] and in WB.[3]

Zhejiang Marine Fisheries Research Institue (ZMFRI)

ZMFRI was established and started its research program in the early 1950's. Since then it has carried out fisheries research on a variety of stocks including the large yellow croaker, *Pseudosciaena crocea*; the small yellow croaker, *P. polyactis*; and the edible jellyfish, *Rhopilema esculenta*, in Zhejiang Province and especially in the Zhoushan Archipelago. Mariculture research started in the early 1960's, and in 1972 an important mariculture program was started in ZMFRI's laboratories in Shenjiamen (Fig. 2) on Zhoushan Island. Work continued there until 1984. By 1979 the effects of increasing industrialization of Hangzhou Bay on the general conditions in and around the Zhoushan Archipelago, together with the establishment of important shipyards, a large fishery, freezer plants, and related industrial developments in Shenjiamen, led to reduced water quality at the ZMFRI's laboratories. This impacted mariculture development.

[2] Asian Development Bank. 1993. Final Report of the Zhoushan Island Fisheries Project (unpubl.)

[3] World Bank. 1995. Final report of the Hangzhou Bay Project (unpubl.). This presents a recent multidisciplinary, synthetic review about the water quality and oceanography of Hangzhou Bay and the East China Sea fisheries.

Therefore in 1984 the Xixuan Aquatic Experimental Station was established on Xixuan Island, about 10 n.mi. and 30–45 minutes by sea from Shenjiamen (Fig. 2). Xixuan Island has an area of 0.45 km,[2] of which 0.15 km^2 is devoted to culture ponds, principally to *Penaeus orientalis* spawning and grow-out. As the techniques for large-scale mariculture and restocking of *P. orientalis* were successfully mastered, additional tanks have been built to allow mariculture research, grow-out, and restocking of the following species: jellyfish, *Rhopilema esculenta*; abalone, *Haliotis diversicolor* and *H. discus*; Gulf scallop, *Agropecten irradians*; black porgy, *Mylio macrocepahalus czerkskii*; and grouper, *Epinephelus awaara.*

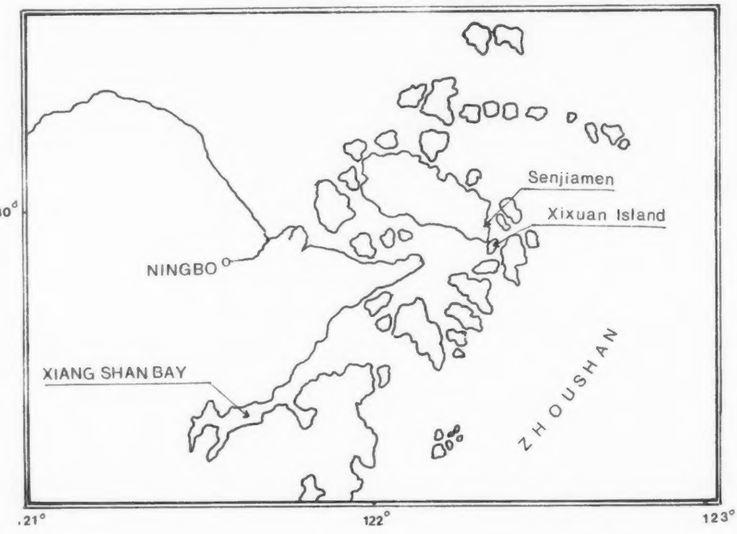
An important part of the Xixuan Island culture facility is the capability to produce live food for cultures, based on large-scale phytoplankton and zooplankton production of *Phaeodactylum tricornutum, Chaetoceros calcitrans, Skeletonema costatum,* and *Brachionus plicatilis.* Up to about 1,000 t/yr of phytoplankton is produced at various densities, usually at about 4 ml/1. These organisms are used to feed the newly hatched and young stages of the cultured organisms.

Stocking and Enhancement

The crustacean fishery in the East China Sea landed about 131,000 t in

1956 (the first year for which landings data are available), increasing to about 884,000 t in 1994. The species composition of these landings is not monitored but is known to be dominated by crabs and palaemonid shrimp, with <1% being composed of penaeids. The only penaeid fished in commercially important amounts is *P. orientalis* which is taken regularly from a very small stock located near the mouth of the Changjiang. This stock has provided a fishery with significant but small (<1,000 t/yr) landings over the last 20–30 years (WB,[3] Chen[4]). This stock has been used by Chinese scientists in Zhoushan and Shanghai as a source for broodstock when needed.

Figure 2. — Location of the study area. Inset: Location of research stations and areas in the southern Zhoushan Islands.



Stocking in Xiang Shan Bay

P. orientalis was stocked by releasing large numbers of 3.0–4.0 cm TL (total length) shrimp cultured at the Shenjiamen Laboratory (until about 1983) and at the Xixuan Mariculture Station from 1985 onwards, in Xiang Shan Bay, an area where *P. orientalis* never occurred prior to stocking. Catches of *P. orientalis* resulting from stocking were estimated by two different methods: direct interviews with fishermen provided estimates of the numbers of *P. orientalis* recaptured; and landings data compiled by local Fisheries Management Bureaus, through weighing of catches at the landing places and estimating the catch in metric tons fresh weight (Table 2). Low releases and catches occurred until 1986 when the new facilities at the Xixuan station came fully on line. Numbers of *P. orientalis* released exceeded 100,000,000/yr for the first time in 1986, and declined from about 1991 when numbers stocked were decreased. By 1993 when stocking ceased, landings of *P. orientalis* were again very low, with negligible landings in 1994.

Releases of small shrimp occurred in May–June, and recaptures of juveniles in the commercial fishery occurred from July to December when shrimp reached 10–12 cm TL (Table 3). Larger, mature shrimp were taken in small numbers, usually in the mouth of Xiang Shan Bay in March and April of the following year. Mature shrimp left the Xiang Shan mouth fishing grounds or died out of the population by May. No mature prawn were ever taken in the fishery from May onward when recruitment would be expected in a natural population. Conditions in the sea were suitable for grow-out but, in spite of the occurrence of some mature individuals in the population, the restocked *P. orientalis* population was not reproduc-

[4] W. Z. Chen, East China Sea Fisheries Research Institute, 300 Jun Gong Lu, Shanghai, 200090, PRC.

Table 2.—Numbers of *P. orientalis* released and landings in Xiang, Shan Bay.

Year	Released (×10,000)	Catch (t)	Year	Released (×10,000)	Catch (t)
1982	239.2	5.0	1988	15,644.3	329.0
1983	164.5	7.0	1989	16,218.0	228.0
1984	793.9	15.8	1990	14,874.2	265.0
1985	0.0	4.4	1991	9,158.0	158.0
1986	13,873.2	135.0	1992	10,950.0	163.0
1987	22,483.0	398.0	1993	0.0	27.0

Table 3.—Relation between numbers of juvenile *P. orientalis* released and numbers recaptured by the fishery.

	Releases (×10,000)			Catch of juveniles (×10,000)			Catch of matures (×10,000)			
Year	April/May	July	August	Sept.–Oct.	Nov.–Dec.	Mar.–Apr.	Total No. landed	% of the releases landed	Matures as % of recaptures	Matures as % of releases
1986	13,873.2	709.0	125.0	67.0	35.0	7.0	943.0	6.8	0.00	0.000
1987	22,483.0	1,083.0	167.0	156.7	243.0	24.0	1,673.4	7.4	1.43	0.1067
1988	15,644.3	1,707.0	208.4	67.2	75.0	12.0	2,069.6	13.3	0.58	0.0767
1989	16,218.0	1,174.0	167.0	112.0	75.0	15.0	1,543.0	10.5	0.97	0.0925
1990	14,874.2	1,005.0	132.0	120.0	63.0	12.0	1,332.0	9.1	0.90	0.0807

tively successful, nor were large numbers of ripe individuals taken in or near Xiang Shan Bay at any time. Ripe individuals provided only 0.05–0.15% of all *P. orientalis* taken in the commercial catches.

The lack of any *P. orientalis* in Xiang Shan Bay prior to the initiation of restocking in 1982, the decline to nearly zero landings in 1994 after restocking was suspended in 1990, together with results of the tagging experiments, show conclusively that the landings were obtained solely from the stocking operation. Stocking studies reported outside of China are mostly hampered by the need to estimate the amount of shrimp landed that originated from the natural and the restocked shrimp. Such separation of shrimp taken in commercial catches is technically demanding and often leads to difficulties not encountered in the Xiang Shan Bay project as noted by Kurata (1981) working on *Penaeus japonicus* in the Inland Seto Sea of Japan.

The success of *P. orientalis* restocking in Xiang Shan Bay over more than a decade is shown in Table 2: when numbers of released shrimp exceeded 100,000,000/yr, landings were over about 100 t/yr. Figure 3 shows the least squares regression of total *P. orientalis* catch in Xiang Shan Bay on the numbers of restocked juveniles of the same cohort: the regression is highly significant ($r = 0.9637$ at 9 df; $t = 11.4159$, $P < 0.00001$ for the slope; $t = 0.1791$, $P = 0.8614$ for the intercept, which was not significantly different from zero; F ratio for the model was 130.3/6.71, $P < 0.00001$; $R^2 = 92.87\%$). The residuals showed no pattern; the largest deviations from the predicted values occurred in 1986 and in 1988. In 1986, unusually low landings occurred (135 t observed and about 245 t predicted from the model), and were probably caused by technical difficulties associated with training staff during the first massive releases of small juvenile *P. orientalis*. In 1988, landings were about 65 t higher than predicted by the model: survival was the highest on record in that year (Table 3), probably because of unusually favorable environmental conditions and/or an earlier than usual opening of the Xiang Shan Bay fishery in that year.

The relation between catch and numbers of 3.0–4.0 cm TL juveniles released (Fig. 3) was:

$$\text{Catch} = 3.0696 + 0.000001679 \times N \quad (1)$$

where Catch = total catch in t/yr of *P. orientalis* from July to the following April, and N = the number of 3.0–4.0 cm TL juveniles released in May–June. The linear relation between Catch and N shows that catches do not decline with increasing numbers of shrimp into Xiang Shan Bay, i.e. diminishing returns did not occur over the observed range of numbers released. Equation (1) also estimates that around 596,000 juveniles must be released to provide about 1.0 t of *P. orientalis*. This compares with about 200,000 fry needed to produce 1.0 t of *P. japonicus* in the Inland Seto Sea restocking of *P. japonicus* (estimated from data in Kurata (1981)). The lower number of fry required to produce 1.0 t of *P. japonicus* is probably due to use of large, specially designed nursery grounds that were used to allow the shrimp to become accustomed to life in the sea and to protect them from high initial predation in Japan. This step was not taken in China.

The cost:benefit (C:B) ratio increases in a roughly linear fashion with the numbers of juvenile *P. orientalis* released (Fig. 4); although the data are sparse, they suggest clearly that large catches and high profits could be obtained from a larger operation. At some level >225,000,000 juvenile *P. orientalis*, diseconomies from scale will occur (i.e. the C:B ratio will cease to increase, and may even decrease, with number of juveniles released; Fig. 4). At some unknown level of releases, the catch will cease to rise proportionately to the numbers of shrimp released (Fig. 3). However, available data do not allow any estimate of the levels at which these limitations on stocking will occur. Perhaps stocking would become uneconomic in the range from 2–3 times to 10 times the present levels, giving a possible range for stocked landings in the region of 800–4,000 t/yr. A strategy of slowly increasing stocking numbers would allow identification of a level of releases that can produce high landings combined with a profitable C:B ratio.

Enhancement of Jellyfish Landings in Zhoushan

Jellyfish were abundant in the 1960's and 1970's but landings in Zhoushan fell drastically from a mean of 8,800 t/yr in the 1960's to a mean of 800 t/yr in the 1980's and to <200 t/yr in 1991–92. This decline was thought to be caused by a combination of overfishing and pollution.

Because of the long-term trend toward lower landings, ZMFRI established a jellyfish restocking project in

Table 4.—Cost:Benefit (C:B) ratios.

Year	Releases (×10,000)	Landings (t)	C:B (Yn/Yn)
1986	13,872.2	135.0	1:3.0
1987	22,483.0	398.0	1:7.8
1988	15,644.3	329.0	1:5.7
1989	16,218.0	280.0	1:5.7
1989	14,874.2	265.0	1:5.9
Mean			1:5.2

1983. Several years of fundamental research provided the basic biological knowledge needed. Growth from the fertilized egg to about 1.0 cm disc size takes about 1.0 month (Fig. 5), with a survival of about 90%, and 1.0 cm jellyfish are restocked in February or March. By May they reach 10–20 cm and by August about 50 cm. Fishermen reported significantly greater landings in 1990–92 following experimental releases of up to 100,000,000 1.0 cm jellyfish at the beginning of each year. Preliminary cost-benefit analysis shows that C:B ratios for jellyfish restocking range from 1:2 to 1:4, depending on numbers released, mortality rates, and the size at harvest.

Mariculture for Seed and Grow-out

Penaeus orientalis

Restocking was phased out at the Xixuan Island mariculture facility, starting in 1990 and was suspended in 1993. Culture tanks were then used to hold a limited number of shrimp and grow them from the 3–4 cm TL size at which they were previously released into Xiang Shan Bay in May–June, to about 12 cm TL which is reached around October or November; they are then harvested and sold commercially. In November of 1993 > 40 t of *P. orientalis* were harvested and sold for about Yuan 1,600,000.[5] Profits (>Yuan 1,000,000) were used to finance mariculture and assessment research.

Haliotis diversicolor, H. discus

Abalone are very much appreciated in all parts of China and a combination of expanding demand, increasing prices, and falling catches from abalone capture fisheries has led to interest in abalone mariculture. *H. diversicolor* and *H. discus* are being produced at pilot culture levels at the Xixuan Island mariculture facility. Spawning occurs in May, and growth to about 2.0 cm TL takes about 1.0 yr (Fig. 6). In 1993, about 10,000 abalone of 2.0 cm TL, surplus to research requirements, were sold to fishermen/small-holders at 1.0 Yuan/individual, and smaller numbers have been sold over the last few years. The small abalone are held in grow out tanks for up to two years by small-holders and will reach the commercial size of about 5.0 cm TL in about 2 years (i.e. at a total age of about 3.0 yr) when they are worth about Yuan 10–15 each; survival rates are usually about 80%. An average profit of about Yuan 70,000, on a sale of 10,000 individuals, may be made in 2 years: $(10{,}000 \times 10 \times 0.8) - 10{,}000 =$ Yuan 70,000. This provides a satisfactory margin for small-scale grow out by farmers. The commercial-scale viability of the *Haliotis* spp. cultures will be determined when large-scale sales of seed are carried out during the next 3–5 years.

Gulf Scallop, *A. irradians*

A. irradians reaches 6–7 cm TL in nature but landings from wild stocks are now very low. The preferred commercial size is about 5.0 cm TL. *A. irradians* spawns in March–April at temperatures

[5] 40 Yuan/kg, i.e. ca US\$4.65/kg; US\$1.00 = Chinese Yuan 8.62 in 1995.

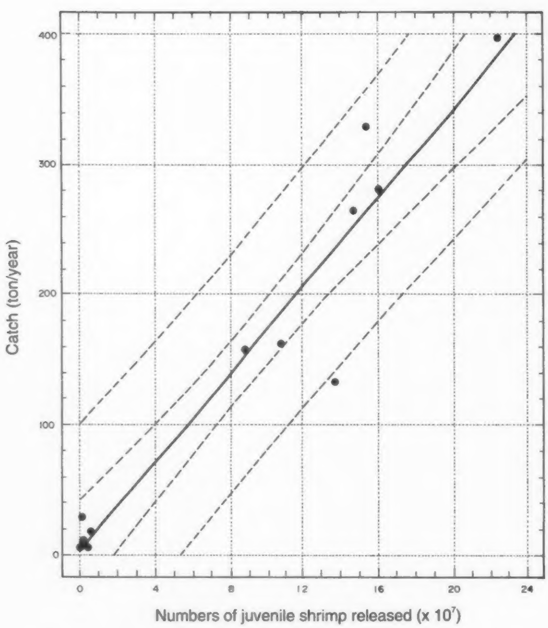


Figure 3. — Relation between numbers of juvenile (3–4 cm TL) *P. orientalis* stocked in Xiang Shan Bay in April/May, and the landings of stocked *P. orientalis* from June until the following March/April. Number = number $\times 10^7$ of juvenile *P. orientalis*; Catch = *P. orientalis* landings from Xiang Shan Bay, t/yr.

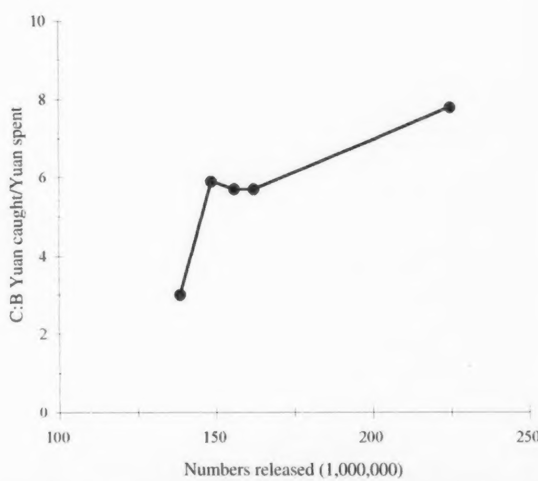


Figure 4. — Cost:Benefit (C:B) ratio for *P. orientalis* restocking in Xiang Shan Bay, 1986–89.

of about 20–25°C and reaches commercial size by about November, when they are worth about Yuan 6.0–10.0/kg. Spat settle a few hours after spawning and reach about 0.1 cm TL in less than a month, i.e. around April–May, when they are sold to fishermen for Yuan 0.02/ individual. Around 20,000,000 small *A. irradians* were sold in April–May 1993 for a total of Yuan 400,000. Survival during grow-out to market size by small-holders varies from 10 to 20%. The small-holders who grow the *A. irradians* are mostly low-income farmers and fishermen who operate very small, part-time enterprises, so that a substantial (cash) addition to family income for many families is made by a small grow-out operation.

Figure 5. — Edible jellyfish, *Rhopilema esculenta*, about 1.0 cm disc diameter and ready for restocking, produced at the Xixuan Island Mariculture Station, Zhejiang Marine Fisheries Institute.

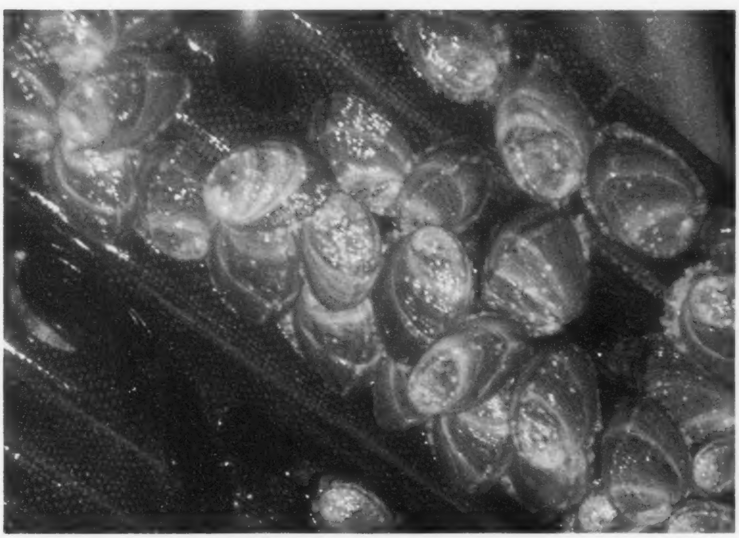


Figure 6. — Cultured abalone about 2.0 cm TL (1.0 year old), produced at the Xixuan Island Mariculture Station, Zhejiang Marine Fisheries Institute.

Experimental Cultures

In addition to the larger scale activities described above, experimental cultures have been started on two species of fish: *M. macrocepahalus* and *Epinephelus awaara*. The former porgy grows to a maximum of around 3–4 kg total weight (TW) and the latter to around 10 kg TW, although cultured fish would be harvested at a smaller size. Work is currently aimed at achieving:

1) routine spawning on as large a scale as desired in a controlled environment,
2) grow-out to desired sizes in controlled conditions, and
3) determining in detail the technology required for successful, large scale restocking and growth to market size.

Technology obtained through systematic research in this way will be used by the end of the next decade or so as the basis for commercial production of these species.

Discussion

Constraints on *P. orientalis* Stocking

The mean C:B ratio from *P. orientalis* restocking in Xiang Shan Bay was 1:5.2, i.e. Yuan 5.2 earned for each Yuan 1.0 spent (Fig. 3). This compares favorably with the C:B ratio for *P. japonicus* restocking in the Inland Seto Sea of Japan, which was only 1.0:1.79 (i.e. Yen 1.0 spent on restocking per Yen 1.79 earned from the commercial fishery (Kurata, 1981)). The cost of restocking in China was probably reduced by cheap labor, and perhaps also because there was no need to construct the special nursery grounds used in Japan for releasing *P. japonicus* into the sea. Chinese and Japanese data cited here include all costs of production and so are comparable.

The new economic policy in the PRC, based on the market economy, led to withdrawal of financial support from the Xiang Shan Bay stocking project in 1993. This occurred in spite of the technical and economic successes, largely

because there was no practical way for government funding agencies to recover the costs of stocking from the income generated by the fishermen who harvested the shrimp. Many of the fishermen operating in Xiang Shan Bay are, however, organized into cooperatives, each of which has access to certain fishing areas. It is conceivable that a new stocking project might eventually be financed through cooperatives which, in collaboration with the Provincial Government and by means of co-management structures, could control access to trawling and gill netting in Xiang Shan Bay. Funding for *P. orientalis* stocking could eventually be provided by the people benefiting from the landings. It is likely that financing the re-stocking of other species, such as jellyfish, could be tackled in this way. This approach cannot be undertaken successfully without a complete biological and socioeconomic survey; nevertheless, it is already clear that the constraints on successful *P. orientalis* stocking are likely to be mainly financial, rather than technical or economic.

Establishment of a *P. orientalis* Breeding Population

A second reason for withdrawing financial support from the *P. orientalis* Xiang Shan Bay stocking project was its failure to establish a self-perpetuating, reproductive stock of shrimp. The highest captures of mature *P. orientalis* from Xiang Shan Bay occurred from the May–June 1987 restocking: 240,000 were taken in March–April of 1988, giving a survival rate of 0.1% (Table 3). These 240,000 individuals were spread over an area of around 150 km^2, near the mouth of Xiang Shan Bay; i.e. at an average density of about 1,600 shrimp/km^2 (625 m^2/shrimp) or (assuming a mean weight of about 20 g/shrimp) about 32 kg/km^2. These levels are low compared with the levels at which mature shrimp occur in well known shrimp fisheries, e.g. about 200–500 kg/km^2 for *P. semisulcatus* in Kuwait in the 1960's and *P. stylirostris* and *P. vannamei* in Mexico in the 1970's (estimated from data in Mathews, 1981), around 100 kg/km^2 in Saudi Arabia in the 1980's and 100–200 kg/km^2 in Kuwait in the 1990's (from Mathews et al., 1993).

Densities of mature shrimp are much greater in most of these stocks (by up to 10 times) and the proportion surviving to spawn was probably also much higher. Therefore it is possible that the density of adult *P. orientalis* in Xiang Shan Bay never reached a sufficiently high level for mating and spawning on a large scale to be feasible. A new stocking project targeted to increase landings by up to 10 times in Xiang Shan Bay would probably increase the proportion of mature shrimp by 5–10 times, i.e. to about 250–500 kg/km^2. If stocking was accompanied by protection of those fishing grounds characterized by especially high numbers of adults from excessive effort, it is possible that the density might become high enough for massive spawning to occur naturally. A self-maintaining population might eventually be established.

The cost of fisheries enhancement is significant, and the analysis suggests that it would be prudent to carry out ecological research prior to any continuation of *P. orientalis* enhancement in Xiang Shan Bay. This could include 1) comparative studies of environmental conditions in Xiang Shan Bay and in areas where *P. orientalis* is well established and 2) research on the relation between recruitment of young shrimp and the density of spawners that produce them in areas where endemic populations of *P. orientalis* occur.

Acknowledgments

We are grateful to Wu Jiazhui, Vice Director of the Zhejiang Aquatic Bureau, and Zen Ping of the Zhejiang Environmental Protection Bureau, both of whom supported our work. We are, however, responsible for any errors.

Literature Cited

FAO. 1992. Fisheries statistics, 1991. Food Agric. Organ., U.N., Rome, 647 p.

________. 1994. Fisheries and aquaculture statistics, 1993–94. Food Agric. Organ., U.N., Rome, 700 p.

Kurata, H. 1981. Shrimp fry releasing techniques in Japan with special reference to the artificial tideland. *In* Proceedings of the International Shrimp Releasing, Marking and Recruitment Workshop, 25–27 November 1978, Salmiya, State of Kuwait. Kuwait Bull. Mar. Sci. 2:117–148.

Mathews, C. P. 1981. A review of North American penaeid fisheries, with particular reference to Mexico. *In* Proceedings of the International Shrimp Releasing, Marking and Recruitment Workshop, 25–27 November 1978, Salmiya, State of Kuwait. Kuwait Bull. Mar. Sci. 2:352–412.

________, S. Kedidi, I. Al-Qader, A-K. Radhi, N. I. Fita, and A. Al-Yahya. 1993. Report on the effects of the 1990/91 Iraq/Kuwait war on the North Western Gulf Prawn stocks. IUCN World Conserv. Union, pt. 3:1–92.

Ning, X. I. 1994. Fishery conditions in the East China Sea: future opportunities and suggestions. *In* Asian Develop. Bank Interim. Rep. 1993.

A Brief History of Bycatch Management Measures for Eastern Bering Sea Groundfish Fisheries

DAVID WITHERELL and CLARENCE PAUTZKE

Introduction

Bycatch management measures instituted for groundfish fisheries of the eastern Bering Sea have focused on reducing the incidental capture and injury of species traditionally harvested by other fisheries. These species include king crab, *Paralithodes* and *Lithodes* spp.; Tanner crab, *Chionoecetes* spp.; Pacific herring, *Clupea harengus pallasi*; Pacific halibut, *Hippoglossus stenolepis*; and Pacific salmon and steelhead trout, *Oncorhynchus* spp. Collectively, these species are called "prohibited species," as they cannot be retained as bycatch in groundfish fisheries and must be discarded with a minimum of injury.

Regulations promulgated in the 1940's and 1950's prohibited taking and retaining these species except by specific gear types. The concept of prohibited species was incorporated into regulations implemented following passage of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) in 1976, first for controlling foreign fisheries within the U.S. Exclusive Economic Zone, and then for the development of domestic fisheries thereafter. The North Pacific Fishery Management Council (NPFMC) and the National Marine Fisheries Service (NMFS) have enacted many management measures to allocate, control, and reduce the incidental take of prohibited species in groundfish fisheries. This paper provides a historical review of these measures and analysis of their effectiveness.

The authors are with the North Pacific Fishery Management Council Staff, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501. Views or opinions expressed or implied are those of the authors and do not necessarily reflect the position of the Council or the National Marine Fisheries Service, NOAA.

Pre-Magnuson Act Era

Prior to enactment of the MFCMA in 1976, fishery management measures in the eastern Bering Sea were implemented through public laws and international agreements. The early regulations applied only to the U.S. 3-mile territorial sea and were administered by the Bureau of Commercial Fisheries through 1959. Thereafter, they were administered by the Alaska Department of Fish and Game when Alaska gained statehood. Prior to 1950, salmon constituted the primary fishery in the Bering Sea; Pacific halibut, sablefish, *Anoplopoma fimbria*; rockfish, *Sebastes* spp.; flatfish, *Pleuronectes* and *Hippoglossoides* spp.; and king crab fisheries developed in the late 1950's. As these fisheries developed, regulations were promulgated to prohibit the harvest of certain species by particular gear types (Table 1). This set the stage for bycatch and allocation disputes among fishermen using the different gear types. These disputes continue to the present day.

The International Convention for High Seas Fisheries of 1959 was the governing treaty for fisheries outside the U.S. territorial sea. It entered into force in June 1953. The Convention established the International North Pacific Fisheries Commission to provide scientific information and recommendations on conservation measures to ensure maximum sustained productivity of fish resources. One of the Convention's new regulatory measures was a provision that Japan (the only foreign fleet active in the eastern Bering Sea at the time) was prohibited from fishing halibut in certain areas and from trawling in the Bristol Bay Pot Sanctuary to minimize interaction with the red king crab, *Paralithodes camtshaticus*, pot fishery (Fig. 1). A more comprehensive review of early fishery management in the North Pacific is provided by Fredin[1].

In 1966, the U.S. congress established a 9-mile contiguous fishery zone adjacent to the 3-mile territorial sea. Bilateral agreements with Japan and the U.S.S.R. were first initiated in 1967, and made biannually thereafter (Fredin[1]). Provisions of the agreements included continuation and expansion of the Bristol Bay Pot Sanctuary, and an array of area closures to prevent foreign fisheries from targeting on Pacific halibut or having gear interactions with domestic fisheries. The 1975 bilateral agreements established the Winter Halibut Savings Area (Fig. 1) in which trawling was prohibited by all vessels from December through March, and a large zone between long. 170° W and 175° W closed to trawling by Japanese vessels. The Pacific halibut stock had declined throughout the 1960's, and the intent of these closures was to reduce bycatch and rebuild the Pacific halibut resource.

Regulated Foreign Fisheries, 1976–84

Passage of the MSFCMA in 1976 ushered in a whole new era of fishery management in the North Pacific. Un-

[1] Fredin, R. A. 1987. History of regulation of Alaska groundfish fisheries. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Northwest Alaska Fish. Cent. Proc. Rep. 87-07, 63 p.

der this Act, the United States declared exclusive management authority over all fish resources out to 200 n.mi., and

Table 1.—Time line of management measures to control bycatch of prohibited species in the groundfish fisheries of the Bering Sea and Aleutian Islands area, 1935–97.

Year	Regulation
1935	Trawls prohibited except for shrimp and flounder fishing.
1937	Use of dynamite prohibited.
1938	Use of gillnets prohibited for catching halibut.
1942	Trawls permitted except for salmon and herring fishing.
1944	Use of trawls prohibited for catching halibut.
1948	5-inch minimum mesh size required for trawls.
1959	Trawls prohibited for taking any crab species. Trawling prohibited in Bristol Bay king crab pot sanctuary.
1967	Halibut nursery area closed to halibut fishing. Foreign fisheries prohibited around Fox Islands.
1969	Pribilof Islands area closed to foreign fishing.
1972	Pot gear prohibited for catching halibut.
1973	Use of tangle nets prohibited for catching crab.
1974	Catch quotas established for Japanese groundfish fisheries limit effort.
1975	Catch quotas established for USSR groundfish fisheries. Trawling prohibited in winter halibut savings area and along most of the Aleutian Islands.
1976	Magnuson Act passes, providing national standards and regulations.
1977	Preliminary BSAI Groundfish FMP implemented with several closure areas.
1982	BSAI Groundfish FMP implemented. Chinook salmon bycatch limits established for foreign trawlers.
1983	Halibut, salmon, king crab, and Tanner crab bycatch reduction schedule established for foreign trawling. Domestic trawling allowed in pot sanctuary and Halibut Savings Area.
1984	Further reductions in salmon bycatch limits for foreign trawling. Two million metric ton (t) optimum yield cap on groundfish established.
1987	Bycatch limits and zones established for red king crab, Tanner crab, and halibut taken in domestic and JV flatfish trawl fisheries. Area 512 closed to all trawling year-round.
1989	Bycatch limits for crab and halibut apply to all trawl fisheries. Area 516 closed to trawling seasonally during crab molting period.
1990	New observer program and data reporting system implemented.
1991	VIP established for red king crab and halibut bycatch. Herring Savings Areas established. Season for yellowfin sole fishery changed to May 1.
1992	Hotspot authority granted. VIP expanded for all trawl fisheries. Halibut PSC limits established for BSAI nontrawl fisheries.
1993	Gillnets and seines prohibited for groundfish fishing. Careful release requirements established for halibut bycatch in groundfish longline fisheries. Crab bycatch performance standards set for pelagic trawl fishery.
1994	Council adopts minimum mesh size requirements for trawl codends used in pollock, cod, and rock sole fisheries. Voluntary retention of salmon for food banks allowed. NMFS publishes vessel specific bycatch rates on the Internet.
1995	Chum Salmon Savings Area, Chinook Salmon Savings Area, and Pribilof Islands Habitat Conservation Area established as trawl closure areas. Bottom trawling prohibited in Red King Crab Savings Area established by emergency rule. Halibut and sablefish IFQ program allows retention of halibut in sablefish fisheries.
1996	Red King Crab Savings Area permanently established as year-round trawl closure area.
1997	Nearshore Bristol Bay closed to all trawling year-round. PSC limits for red king crab and Tanner crab reduced. PSC limits for snow crab implemented.

prohibited fishing by foreign vessels except as authorized under certain conditions. A major goal of the Act was to "Americanize" the fisheries off U.S. coasts. The Act required preparation of fishery management plans (FMP's) to achieve and maintain optimum yield from each fishery in accordance with seven national standards for conservation and management. A preliminary FMP for Bering Sea groundfish fisheries was implemented in 1977 with the objectives of rebuilding depleted groundfish and halibut stocks and preventing overexploitation of healthy stocks. This preliminary plan set up both the pot sanctuary and the winter halibut savings area no-trawl zones.

A FMP for Bering Sea and Aleutian Islands (BSAI) groundfish was formally implemented in 1982. The fisheries at that time were prosecuted primarily by foreign fleets from Japan, U.S.S.R., and the Republic of Korea. The pot sanctuary and halibut savings area were included in the original FMP, but the plan was amended in 1983 to allow domestic trawling within the areas. An overall management goal of the FMP is to minimize prohibited species catch (PSC) while attaining optimum yield of groundfish species. In 1982, the FMP was amended to establish a prohibited species catch limit of 55,250 chinook salmon, *O. tshawytscha*, for foreign trawl fisheries, which were annually allocated among foreign nations. Any nation that exceeded their salmon allocation would be prohibited from fishing in much of the Bering Sea for the remainder of the season. This amendment set a precedent for fleet-wide bycatch limits that trigger area or entire fisheries closures.

In 1983, the FMP was amended to reduce the incidental catch of Pacific halibut (50% reduction), Pacific salmon (75% reduction), and king and Tanner crabs (25% reduction) by the foreign trawl fisheries over a 5-year period. The FMP provided incentives for reaching this goal by allocating supplemental groundfish within a fishing season to nations on the basis of their bycatch performance. The Japanese fleet successfully accomplished bycatch reductions by allocating their bycatch allowance among participating vessels. If a vessel allocation was exceeded for any species, that vessel had to stop fishing unless it purchased unused bycatch shares from other vessels. This system

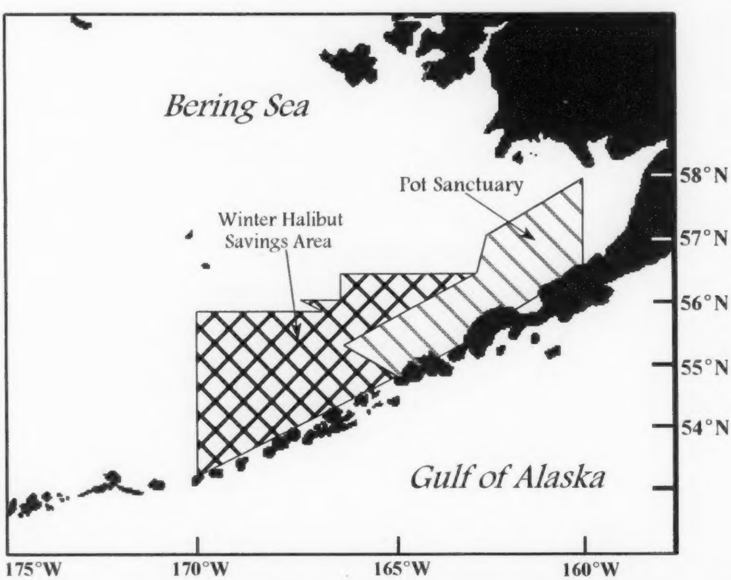


Figure 1. — The Bristol Bay Pot Sanctuary and the Winter Halibut Savings Area.

resulted in an overall bycatch savings by the entire fleet, and it represented the first working system of individual vessel bycatch accountability.

Joint Ventures and Developing Domestic Fisheries, 1985–88

The transition period from foreign to fully domestic groundfish fisheries was stimulated by a rapid increase in joint-venture (JV) operations. The American Fisheries Promotion Act (the so-called "fish and chips" policy) required that allocations of fish quotas to foreign nations be based on the nations contributions to the development of the U.S. fishing industry. This provided sufficient incentive for development of JV operations, with U.S. catcher vessels delivering their catches directly to foreign processing vessels, and moving to fully domestic fisheries. Additionally, conservation policies adopted by the NPFMC had the effect of restoring depleted stocks such as yellowfin sole, *Pleuronectes asper*; Pacific ocean perch, *Sebastes alutus*; and sablefish (Megrey and Wespestad, 1990). Based on good management, healthy fish stocks, the potential for hefty profits, and also the Bristol Bay red king crab fishery collapse, vessels were quickly built or converted for participation in JV and domestic groundfish fisheries in the North Pacific.

This transition period was an era of relatively few fishing regulations for U.S. groundfish vessels, and yet bycatch concerns of domestic halibut longliner fishermen and crab pot fishermen were recognized and addressed. In 1987, Amendment 10 to the FMP established bycatch limitation zones (Fig. 2) and PSC limits for red king crab, *C. bairdi*, and Pacific halibut. This amendment specified PSC limits of 135,000 red king crab and 80,000 *C. bairdi* in Zone 1, and 326,000 *C. bairdi* in Zone 2. These PSC limits applied to domestic and JV fisheries for yellowfin sole and other flatfish only. When this fishery reached the specified PSC limit, vessels were prohibited from flatfish fishing within that zone. In addition to PSC limits, all trawling was prohibited from Area 512 (long. 160° W to lat. 162° W, south of lat. 58° N) in Bristol Bay to protect red king crab stocks.

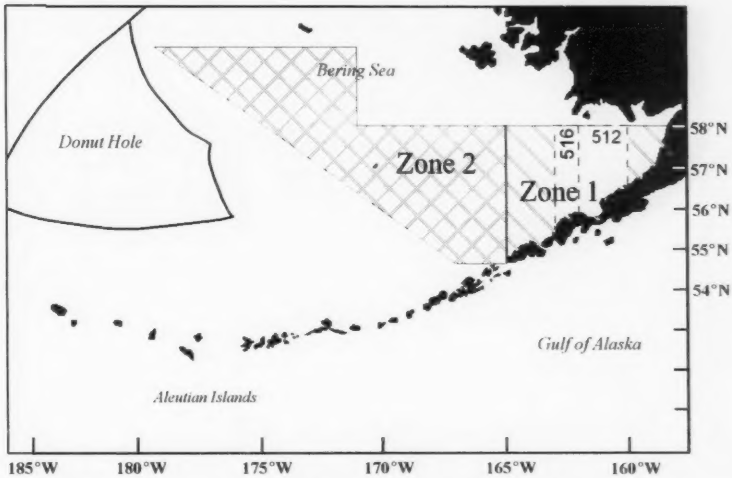


Figure 2. — The crab bycatch limitation zones and Regulatory Areas 512 and 516.

Domestic Fishery, 1988–97

Joint-venture operations peaked in 1987, giving way to a rapidly developing domestic fishery. By 1991, the entire BSAI groundfish harvest (2,126,600 t, worth U.S. $351 million ex-vessel) was taken by only 391 U.S. vessels (Kinoshita et al., 1993). Along with Americanization of the fleet came domestic squabbles over allocation and bycatch, leading to an array of regulations intended to control this bycatch.

In 1989, Amendment 12a to the FMP further addressed bycatch concerns by establishing a seasonal closure in Regulatory Area 516 and establishing bycatch limits for crab and Pacific halibut for all trawl fisheries. Total annual PSC limits were 200,000 red king crab and 1,000,000 *C. bairdi* for a Zone 1 closure, 3,000,000 *C. bairdi* for a Zone 2 closure, and 5,333 t of halibut for a BSAI closure. In 1992, halibut bycatch limits were extended to nontrawl fisheries (Amendment 21) and established in terms of mortality rather than total catch. PSC limits 3,775 t of halibut bycatch mortality for trawl fisheries and 900 t of halibut bycatch mortality for nontrawl fisheries were established. PSC limits are further seasonally apportioned into specified fisheries (Table 2), and several simulation models have been used to analyze alternative bycatch management measures in seeking optimal PSC apportionment (Smith, 1993).

In 1990, the Council adopted a "penalty box" system to penalize individual trawl vessels for excessive bycatch rates by requiring vessels to cease fishing for a set period. This system was disapproved by the Secretary of Commerce based on concerns about due process and the application of observer data. In its place, a vessel incentive program (VIP) was implemented. The VIP imposes fines for vessels exceeding bycatch rate standards. These standards for maximum acceptable bycatch rates are established preseason. Unfortunately, very few cases have been prosecuted due to insufficient staff resources necessary to investigate and prosecute a case.

In 1991, concern about unregulated Pacific herring bycatch in trawl fisheries led to implementation of herring bycatch limits that, when attained, trigger closures of established areas to trawling (Amendment 16a). Areas with relatively high bycatch rates of Pacific herring were identified from data collected by observers on foreign and JV vessels. From this information, three time/area closures (called Herring Savings Areas) were established, taking into account herring migration patterns (Fig. 3). These Herring Savings Areas close to trawling when a herring PSC limit is

attained. Like other PSC limits, the herring PSC limit (set at 1% of estimated herring biomass) is apportioned among specified trawl fisheries. If a bycatch allowance is attained, Area 1 closes 15 June to 1 July, Area 2 closes from 1 July to 15 August, and Area 3 closes during the winter months (1 September through 1 March) for specified fisheries.

Analysis of bycatch and "hotspot" areas was greatly enhanced by the implementation of the domestic observer program in 1990, and development of Geographic Information System (GIS) technology. In the early 1990's, GIS technology was used to evaluate proposed trawl closure areas to protect blue king crab, *Paralithodes platypus*, habitat around the Pribilof Islands, and to define hotspot closure areas to control bycatch of chinook and chum salmon, *O. keta*. The Chum Salmon Savings Area (Fig. 4) closes to all trawling during 1–31 August, and remains closed if a bycatch limit of 42,000 chum salmon is taken in the catcher vessel operational area. Trawling is prohibited in the Chinook Salmon Savings Areas (Fig. 4) upon attainment of a bycatch limit of 48,000 chinook salmon in the BSAI. Beginning in 1995, the Pribilof Islands Habitat Conservation Area (Fig. 5) was closed to all trawling on a year-round basis (Fig. 5).

Closure of the Bristol Bay red king crab fishery in 1994 due to poor stock conditions brought about a flurry of regulatory activity to control crab bycatch. A new trawl closure area, called the Red King Crab Savings Area (Fig. 5), was established by emergency rule in 1995, and made permanent under Amendment 37. This 4,000 n.mi.^{2} area in outer Bristol Bay was a prime fishing ground for rock sole and other flatfish, but it was found to have high densities of adult male red king crab. In adopting this area closure, the Council expressed concerns about bycatch and unobserved mortality of these crab. Amendment 37 also prohibited all trawling on a year-round basis in the nearshore waters of Bristol Bay to protect juvenile red king crab and critical rearing habitat that could be impacted by trawling (Fig. 5). This nearshore area encompasses about 19,000 n.mi.^{2}. The third management measure adopted under Amendment 37 was a reduction of existing PSC limits for red king crab taken in trawl fisheries. Based on the 1996 survey abundance index, the 1997 PSC limit was established at 100,000 red king crab in Zone 1.

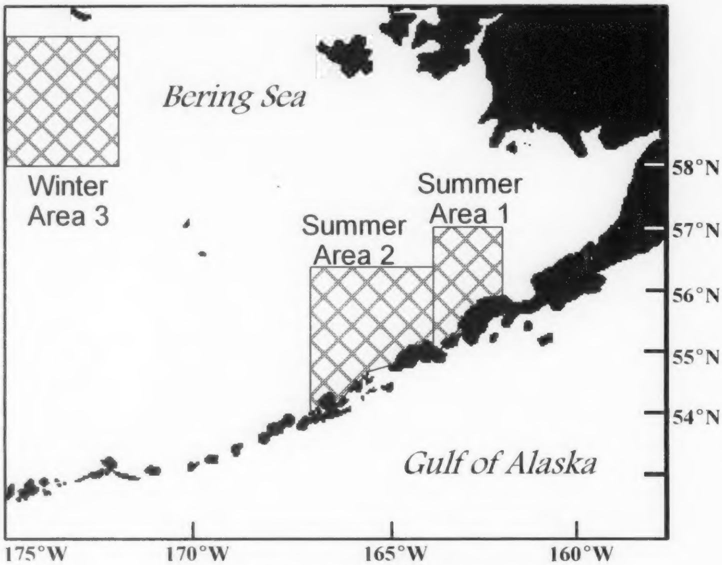


Figure 3. — The three Herring Savings Areas.

Table 2. — Pre-season apportionments of prohibited species for Bering Sea and Aleutian Islands groundfish fisheries, and resulting closures 1996.

Fishery and species	Pacific halibut (mortality in t)	Pacific herring (t)	Red king crab (Zone 1)	Tanner crab (Zone 1)	Tanner crab (Zone 2)	Closure reason 1996
Trawl fisheries						
Yellowfin sole						
Jan 20–Mar 31	160	287	5,000	50,000	1,530,000	Zone 1 Crab 3/20
Apr 1–May 10	150	RO[1]	15,000	200,000	RO	Halibut 6/17
May 11–Aug 14	100	RO	10,000	RO	RO	Halibut 10/26
Aug 15–Dec 31	410	RO	20,000	RO	RO	
Rock sole / other flatfish						
Jan 20–Mar 29	453	NA[2]	110,000	425,000	510,000	Halibut 2/26
Mar 30–Jun 28	139	NA	RO	RO	RO	Halibut 4/13
Jun 29–Dec 31	138	NA	RO	RO	RO	Halibut 6/8, 7/31
Rockfish						
Jan 20–Mar 29	30	7	NA	NA	10,000	
Mar 30–Jun 28	50	RO	NA	NA	RO	
Jun 29–Dec 31	30	RO	NA	NA	RO	
Pacific cod						
Jan 20–Oct 24	1,585	22	10,000	250,000	260,000	Halibut 5/14
Oct 25–Dec 31	100	RO	RO	RO	RO	Halibut 6/23
						Halibut 11/9
Pollock (bottom trawl)/others						
Jan 20–Apr 15	330	154	30,000	75,000	690,000	Halibut 9/7
Apr 16–Dec 31	100	RO	RO	RO	RO	
Pollock (pelagic trawl)	NA	1,227	NA	NA	NA	
Total	3,775	1,697	200,000	1,000,000	3,000,000	
Nontrawl fisheries						
Pacific cod (longline)						
Jan 1–Apr 30	475	NA	NA	NA	NA	Halibut 5/15
May 1–Aug 31	40	NA	NA	NA	NA	Halibut 11/5
Sept 1–Dec 31	285	NA	NA	NA	NA	
Other longline fisheries	100	NA	NA	NA	NA	Halibut 5/15
Groundfish pot fisheries	NA	NA	NA	NA	NA	
Total	900 t					

[1] RO = rollover of remaining allowance until limit is attained.
[2] NA = not applicable.

Two other FMP amendments were adopted in 1996 to manage bycatch of crab. Amendment 41 reduced existing PSC limits for Tanner crab taken in BSAI trawl fisheries. Under this amendment, PSC limits in Zones 1 and 2 are based on total abundance of Tanner crab as indicated by the NMFS trawl survey. Based on 1996 abundance (185 million crabs), the PSC limit was specified at 750,000 crabs in Zone 1 and 2,100,000 crab in Zone 2 for 1997 fisheries. Amendment 40 will establish new PSC limits for *C. opilio*, taken in BSAI trawl fisheries. PSC limits for this species will be based on it's total abundance as indicated by the NMFS standard trawl survey and will be apportioned among trawl fisheries as bycatch allowances. The annual *C. opilio* PSC limit will be set at 0.1133% of its abundance index, with a minimum PSC of 4,500,000 *C. opilio* and a maximum of 13 million. The *C. opilio* taken within the *C. opilio* Bycatch Limitation Zone (Fig. 6) would accrue towards the bycatch allowance specified for individual trawl fisheries. Upon attainment of a *C. opilio* bycatch allowance apportioned to a particular trawl target fishery, that fishery would be prohibited from fishing within the *C. opilio* Bycatch Limitation Zone.

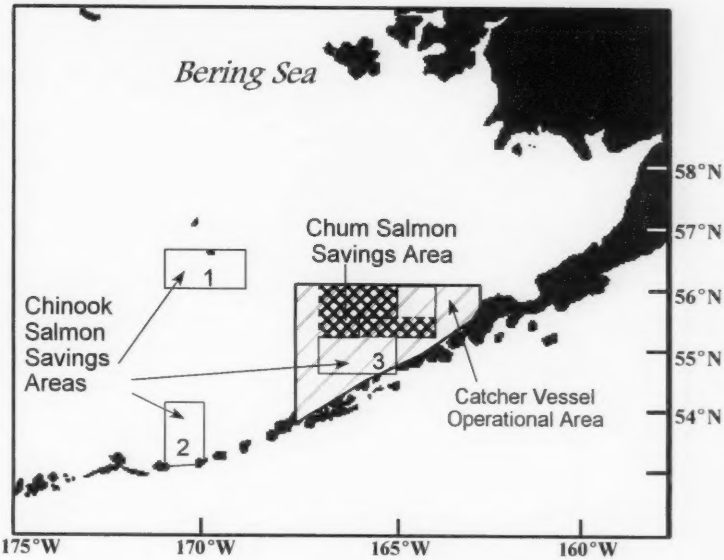


Figure 4. — The Chum Salmon Savings Area, the Chinook Salmon Savings Areas, and the Catcher Vessel Operational Area.

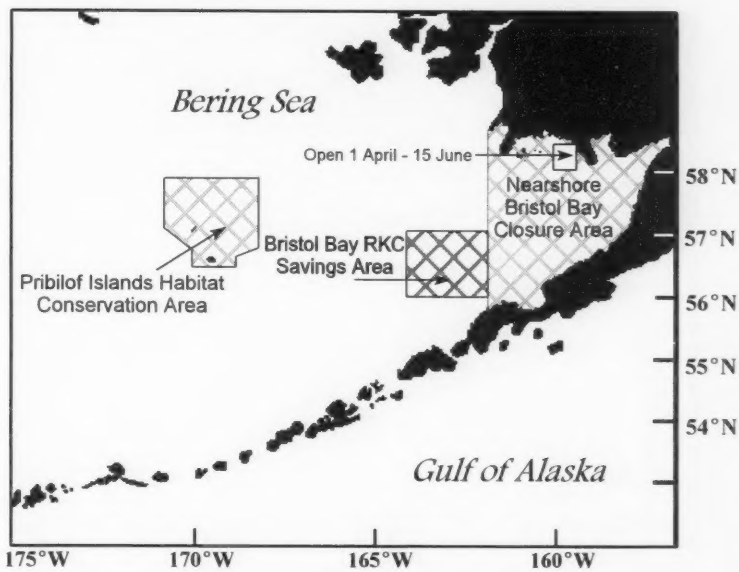


Figure 5. — The Pribilof Islands Habitat Conservation Area, the Red King Crab Savings Area, and the nearshore Bristol Bay trawl closure area.

Discussion

Regulations to control bycatch of certain species have been promulgated primarily to address allocation concerns from competing users of the resource. The bycatch of a prohibited species in the groundfish fishery decreases the amount of those species that can be taken by fishermen in the fisheries for those species, but efforts to decrease bycatch impose costs on groundfish fishermen. Hence, bycatch allocation has been a very contentious issue for the Council process, and will likely continue to be as directed fishery representatives demand more stringent bycatch controls. Unfortunately, optimal allocation of fishery resources among competing users is a problem not easily overcome (Wilson and Weeks, 1996).

One overall goal of the Council has been to maximize groundfish harvests (within biologically acceptable limits) while minimizing bycatch. As such, many regulations have been implemented in the past 20 years to control bycatch and associated mortality of prohibited species in Bering Sea groundfish fisheries. Regulatory measures have included bycatch limits, seasons, gear

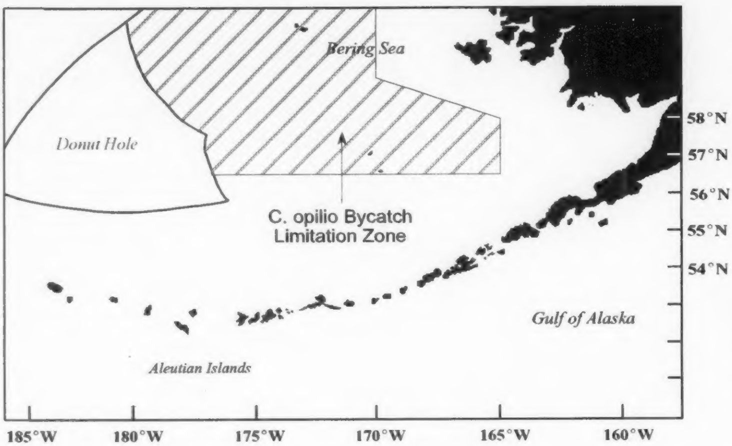


Figure 6. — The *C. opilio* Bycatch Limitation Zone.

Table 3. — Estimated bycatch of Pacific halibut (metric tons of mortality), king crab, Tanner crab, Pacific herring, chinook salmon, and other salmon taken in Bering Sea and Aleutian Islands groundfish fisheries, 1977-96. (1996 data are preliminary).[1]

Year	Pacific halibut (t)	King crab (no., all species)	*Chionoecetes* crab (no., all species)	Pacific herring (t)	Chinook salmon (no.)	Other salmon (no.)
1977	1,758	599,623	17,600,000	NA[2]	47,840	(combined)
1978	3,030	1,227,931	17,300,000	NA	44,548	(combined)
1979	3,269	1,007,796	18,000,000	NA	107,706	(combined)
1980	5,571	1,147,671	11,400,000	783	115,036	6,726
1981	3,866	1,817,152	6,300,000	287	36,218	5,800
1982	2,869	573,919	2,400,000	1,986	15,644	7,686
1983	2,575	1,034,157	3,000,000	2,513	10,334	32,134
1984	2,830	691,088	3,000,000	1,257	11,274	72,195
1985	2,538	1,225,073	2,700,000	4,539	11,069	10,598
1986	3,364	275,066[3]	7,200,000[3]	4,018[3]	9,237	14,433
1987	3,462	147,386[3]	7,400,000[3]	487[3]	22,221	4,799
1988	5,344	88,033[3]	3,100,000[3]	351[3]	30,320	3,709
1989	4,393	207,703[3]	3,800,000[3]	2,527[3]	40,354	5,545
1990	5,176	109,201[4]	1,731,725[5]	3,379	13,990	16,661
1991	6,046	255,607	14,498,270	3,252	35,766	31,987
1992	6,466	315,788	19,613,453	3,758	37,372	38,919
1993	4,684	388,664	18,881,490	1,076	45,964	243,246
1994	5,711	359,436	15,059,028	1,711	43,636	94,508
1995	5,264	48,191[4]	7,695,643	969	23,079	21,780
1996	4,893	28,682[4]	4,730,000	1,510	63,179	77,926

[1] Sources: Guttormsen et al., 1990; Queirolo et al., 1995; NPFMC, 1995; Williams, 1997.
[2] NA = not available.
[3] Foreign and joint-venture bycatch only.
[4] Red king crab only.
[5] *C. bairdi* only.

restrictions, time/area closures, bycatch rate standards, monitoring, and enforcement. Unfortunately, regulations or operational changes designed to reduce bycatch of one species, say Pacific halibut for example, may serve to increase bycatch rates of another PSC species such as Tanner crab. The multispecies nature of bycatch is a dilemma faced by policy makers designing bycatch regulations and fishermen attempting to abide by them.

Beginning in 1982 with the implementation of the BSAI groundfish FMP, regulations and incentives for foreign fisheries worked to control the bycatch of halibut, crab, and salmon (Table 3). Bycatch of these species remained low through 1985, but then increased with development of relatively unconstrained joint-venture operations until 1987 when bycatch limits for these fisheries were established. Bycatch further increased with development of the fully domestic fleet, but was quickly limited by regulation. Bycatch limits for Pacific halibut, Pacific herring, red king crab, and Tanner crab kept the bycatch from reaching higher levels. Bycatch of salmon remained unconstrained through 1994, and bycatch of *C. opilio* remained unconstrained through 1997.

Bycatch of prohibited species has been controlled by bycatch management measures, but not without cost to groundfish fisheries. In particular, halibut bycatch management measures have constrained groundfish harvests. Typically, all bycatch mortality (4,665 t) allocated to trawl and longline fisheries is taken, along with lesser amounts from pot fisheries and fisheries within Alaska state waters (Williams, 1997). Attainment of halibut bycatch mortality limits has caused many closures over the years, and these closures have decreased the amount of groundfish caught. For example, 6 closures were implemented in 1994, 12 closures in 1995, and 14 closures in 1996 due to Pacific halibut bycatch allowances being attained by specific fisheries. A summary of the 1996 closures is shown in Table 2. Pacific halibut bycatch limits have affected bottom trawl fisheries in particular, and consequently, portions of fishing quotas annually specified for most flatfish species have remained unharvested (Witherell, 1995). Longline fisheries have also been constrained by Pacific halibut bycatch, and careful release requirements have been implemented to improve survival of halibut discards (Smith, 1995). However, implementation of an individual fishing quota (IFQ) system for Pacific halibut and sablefish longline fisheries in 1995 allowed for more selective longline fisheries with lower bycatch (Adams, 1995).

Overall crab bycatch has been a function of crab abundance and PSC limits. High bycatches of king crab and *Chionoecetes* crab (mostly *C. opilio*) were taken in the 1970's by foreign fisheries, but regulations and incentives implemented with the FMP in 1982 reduced crab bycatch to much lower levels. In the domestic groundfish fisheries, bycatch of red king crab and Tanner crab have been kept in check with PSC limits for trawl fisheries. Bycatch

of *C. opilio* increased drastically in the early 1990's (Table 3), corresponding to an expanding crab population, so *C. opilio* PSC limits were established in 1996.

Crab bycatch regulations have been based on concerns that trawling impacts crab populations directly in terms of trawl-induced mortality and indirectly through habitat degradation. Observed mortality, as measured by crab bycatch, has accounted for a small percentage of crab populations. For example, bycatch amounted to only 0.5% of the red king crab, 1.2% of the Tanner crab, and 0.1% of the *C. opilio* population on average, for 1992–95 (NPFMC, 1996). Because bycatch is small relative to other sources of mortality, time/area closure are thought to be more effective than PSC limits in reducing impacts of trawling on crab stocks (Witherell and Harrington, 1996). As such, numerous trawl closure areas have been instituted to address concerns about unobserved mortality (crab wounded or killed but not captured), and possible habitat degradation due to trawling and dredging.

The bycatch of Pacific herring and salmon has been controlled by time/area closures triggered by bycatch limits. Pacific herring closures have been effective at maintaining an acceptable level of bycatch in years when herring are abundant on the fishing grounds. This situation occurred in 1992, 1993, 1994, and 1995, when Herring Savings Areas 2 and 3 were closed to trawling for fisheries directed at walleye pollock, *Theragra chalcogramma*; rock sole, *Pleuronectes bilineatus*; yellowfin sole, and other flatfishes. Similarly, salmon bycatch limits are expected to trigger closures only during years when exceptionally high bycatch rates are encountered by the trawl fleet. During the first year of implementation in 1994, the Chum Salmon Savings Area was closed to all trawling from 20 August through 12 November. Without this closure, bycatch may have exceeded the record set in 1993, when over 240,000 chum salmon were taken (Table 3). By far, the highest bycatch rates for chum salmon occur during August, September, and October, with almost no chum salmon taken in other months (NPFMC, 1995).

It should be noted that bycatch of PSC is also controlled by nonregulatory means. Many measures have been embraced by the trawl and longline fleet to control and reduce bycatch of Pacific halibut, crab, and salmon. AGIS application has been used by the BSAI trawl and longline fleet to identify hotspots by using bycatch rates reported by individual vessels (Gauvin et al., 1995; Smoker, 1996). Bycatch rate information from individual vessels is received at a central location, aggregated daily, and then quickly relayed back to the entire fleet in the form of maps, so that hotspot areas can be avoided. PSC rates are reduced and corresponding higher groundfish catches can then be realized by the fleet. Unfortunately, because this is a voluntary program, nonparticipating vessels with high bycatch rates may keep the fleet as a whole from catching the entire quota of flatfish. Some bycatch reduction may also come in the form of peer pressure. Individual vessel bycatch rates are now published on the Internet for all to view. Vessels with high bycatch rates may be shamed into improving their bycatch performance.

Further reductions in bycatch may be achieved with individual vessel incentives. The current system tends to penalize vessels that adopt bycatch reducing tactics because they will probably have reduced catches of target species (Huppert et al., 1992). This external cost is due to the race for fish (and bycatch), as fish are allocated on a first-come-first-served basis. These external costs would be reduced if fishermen paid for the fish they use, or had defined property rights to those resources (NMFS, 1996). Under an individual bycatch quota system, also called a vessel bycatch account (VBA) system, each vessel would have an incentive to reduce its bycatch rate to maximize its catch of groundfish. Vessels with low bycatch rates would benefit by being able to catch additional groundfish without being shut down by vessels with higher bycatch rates, as they are with current fleet-wide bycatch limits. A VBA system could result in more groundfish being caught overall with less overall bycatch of prohibited species. Analysis of a VBA program is underway, and if adopted by the NPFMC and approved, could be implemented in the year 2000.

Acknowledgments

We thank Linda Roberts for assistance with graphics. We also thank two anonymous reviewers for their helpful comments and suggestions to improve the article.

Literature Cited

Adams, D. J. 1995. Bycatch and the IFQ system in Alaska: a fisherman's perspective. *In* Solving bycatch: considerations for today and tomorrow, p. 211–217. Alaska Sea Grant Coll. Rep. 96-03, Univ. Alaska, Fairbanks.

Gauvin, J. R., K. Haflinger, and M. Nerini. 1995. Implementation of a voluntary bycatch avoidance program in the flatfish fisheries of the Eastern Bering Sea. *In* Solving bycatch: considerations for today and tomorrow, p. 79–85. Alaska Sea Grant Coll. Rep. 96-03, Univ. Alaska, Fairbanks.

Guttormsen, M., R. Narita, and J. Berger. 1990. Summary of U.S. observer sampling of foreign and joint venture fisheries in the Northeast Pacific Ocean and eastern Bering Sea, 1989. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWSC-189, 84 p.

Huppert, D. D., L. G. Anderson, and R. Harding. 1992. Consideration of the potential use of individual transferrable quotas in the North Pacific groundfish trawl fishery. U.S. Dep. Commer., NOAA Natl. ITQ Study Rep. vol. 2, 121 p.

Kinoshita, R. K., A. Grieg, and J. M. Terry. 1993. Economic status of the groundfish fisheries off Alaska, 1993. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-54, 108 p.

Megrey, B. A., and V. G. Wespestad. 1990. Alaskan groundfish resources: 10 years of management under the Magnuson Fishery Conservation and Management Act. N. Am. J. Fish. Manage. 10(2):125–143.

NMFS. 1996. The economics of bycatch and bycatch management in the U.S. EEZ groundfish fisheries off Alaska. *In* Our living oceans. The economic status of U.S. fisheries, 1996, p. 42–47. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/SPO-22, 130 p.

NPFMC. 1995. Environmental assessment/regulatory impact review for amendment 35 to the Fishery Management Plan for the groundfish fishery of the Bering Sea and Aleutian Islands area. N. Pac. Fish. Manage. Counc., Anchorage, Alaska, 128 p.

________. 1996. Environmental assessment/ regulatory impact review for amendment 37 to the Fishery Management Plan for the groundfish fishery of the Bering Sea and Aleutian Islands area. N. Pac. Fish. Manage. Counc., Anchorage, Alaska, 268 p.

Queirolo, L. E., L. W. Fritz, P. A. Livingston, M. R. Loefflad, D. A. Colpo, and Y. L. deReynier. 1995. Bycatch, utilization, and discards in the commercial groundfish fisheries of the Gulf of Alaska, Eastern Bering Sea, and Aleutian Islands. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-58, 148 p.

Smith, T. P. 1993. Allocating the incidental catch of crab, halibut, herring, and salmon in the groundfish fisheries off Alaska. *In* G. Kruse, D. M. Eggers, R. J. Marasco, C. Pautzke, and

T. J. Quinn II (Editors), Proceedings of the International Symposium on Management Strategies for Exploited Fish Populations, p. 745–760. Alaska Sea Grant Coll. Rep. 93-02, Univ. Alaska, Fairbanks.
Smith, W. T. 1995. Reduction of halibut bycatch and associated mortality in the Bering Sea cod fishery. Solving bycatch: considerations for today and tomorrow, p. 205–209. Alaska Sea Grant Coll. Rep. 96-03, Univ. Alaska, Fairbanks.
Smoker, J. 1996. Halibut mortality reduction in Alaska hook-and-line groundfish fisheries: a successful industry program. Fisheries bycatch: consequences and management, p. 93–96. Alaska Sea Grant Coll. Rep. AK-SG-97-02, Univ. Alaska, Fairbanks.
Williams, G. H. 1997. Incidental catch and mortality of Pacific halibut: 1962–1996. Int. Halibut Comm. Rep. Assessment Res. Activities 1996, 323 p.
Wilson, W. J., and H. J. Weeks. 1996. Policy and regulatory measures to control incidental mortality of Pacific halibut in groundfish fisheries of the North Pacific Ocean. *In* R. M. Meyer, C. Zhang, M. L. Winsor, B. J. McCay, L. J. Hushak, and R. M. Muth, (Editors), Fisheries resource utilization and policy. Proceedings of the World Fisheries Congress, Theme 2, p. 219–239. Oxford & Hill Publ. Co., New Delhi.
Witherell, D. B. 1995. Management of flatfish fisheries in the North Pacific. *In* Proceedings of the International Symposium on North Pacific Flatfish, p. 573–589. Alaska Sea Grant Coll. Rep. AK-SG-95-04, Univ. Alaska, Fairbanks.
________ and G. Harrington. 1996. Evaluation of alternative management measures to reduce the impacts of trawling and dredging on Bering Sea crab stocks. *In* High latitude crabs: biology, management, and economics, p. 41–58. Alaska Sea Grant Coll. Rep. AK-SG-96-02, Univ. Alaska, Fairbanks.

Assessment of the Distribution and Abundance of Coastal Sharks in the U.S. Gulf of Mexico and Eastern Seaboard, 1995 and 1996

MARK GRACE and TERRY HENWOOD

Introduction

The 1993 FMP for sharks stressed the need for monitoring and assessment of shark populations to determine the efficacy of FMP measures. Prior to 1995, little fishery independent monitoring of small and large coastal shark populations had occurred in the Gulf of Mexico, and only sporadic or localized surveys had been conducted in the western North Atlantic. Developing a program and survey design to address this need has been difficult due to factors that include species diversity, geographic distributions, seasonality, and gear selectivity. Since all of these factors and many others contribute to high variability in catch rates for each of the species of interest, effective survey design with contemporary gear was considered vital for a meaningful project.

Mark Grace and Terry Henwood are with the National Marine Fisheries Service, NOAA, Southeast Fisheries Science Center, Mississippi Laboratories, P.O. Drawer 1207, Pascagoula, MS 39568-1207.

ABSTRACT—During 1995 and 1996, the National Marine Fisheries Service (NMFS), conducted pilot studies to develop survey methodology and a sampling strategy for assessment of coastal shark populations in the Gulf of Mexico and western North Atlantic. Longline gear similar to that used in the commercial shark fishery was deployed at randomly selected stations within three depth strata per 60 nautical mile grid from Brownsville, Tex. to Cape Ann, Mass. The survey methodology and gear design used in these surveys proved effective for capturing many of the small and large coastal sharks regulated under the auspices of the 1993 Fisheries Management Plan (FMP) for Sharks of the Atlantic Ocean. Shark catch rates, species composition, and relative abundance documented in these pilot surveys were similar to those reported from observer programs monitoring commercial activities. During 78 survey days, 269 bottom longline sets were completed with 879 sharks captured.

This report summarizes the result of a 2-year pilot study to develop survey methodology and a sampling strategy for assessment of coastal shark populations in the U.S. waters of the Gulf of Mexico coast and the eastern seaboard (Fig. 1). Analysis of data collected over the course of this study demonstrates the feasibility of a fishery independent approach to monitoring coastal shark populations.

Materials and Methods

Survey Design

Due to lack of prior shark assessment information over much of the study area, survey design for the pilot study incorporated random station selection stratified by depth (3 depth strata were sampled; 10–19.9 fm, 20–29.9 fm, and 30–40 fm). To ensure relatively uniform coverage over the geographic range of the survey, 60 n.mi. latitudinal or longitudinal grids (parallel to the coastline) were selected with a minimum of 3 samples per grid (1 in each depth stratum). For the 1995 U.S. eastern seaboard study (Thompson[1]), some survey sites were selected to replicate previous NMFS, Narragansett Laboratory project site locations (Casey[2], Casey[3], Casey[4]). During the 1995 Gulf of Mexico survey (Grace[5]) and the 1996 U.S. east coast and Gulf of Mexico survey (Grace[6]), all sites were selected based on random stratified sampling design. Additional random stratified sampling sites were selected during the pilot studies between extreme distances or to fully utilize sea days. Effort during 4 longline sets was in waters shallower than 10 fm; catch results for these survey sites are grouped with data for the 10–19.9 fm strata. With the exception of experimental pelagic longline sets, catch results from all survey sites occupied during the pilot studies are included in data analyses.

Selection of the July through September time frame to conduct these surveys was dictated by availability of the vessel. It is known that shark catch rates by species may vary seasonally (NOAA, 1993), but no adjustment for seasonal variations was possible. This is not problematic as long as future surveys are conducted during this time frame. However, if surveys are conducted during different seasons, the resultant indices may not be comparable.

Longline Gear

Monofilament longline gear was selected for these studies because it is the preferred gear of the commercial sector, and because comparison of longline gear versus "Yankee gear" (Branstetter

[1] Cruise results for RELENTLESS 95-03 (2), coastal shark longline assessment survey. Perry Thompson, NMFS Mississippi Laboratories cruise report, 8 p.

[2] Cruise results for WIECZNO (86-01), longline survey of apex predators. Jack Casey, NMFS Narragansett Laboratory cruise report, 37 p.

[3] Cruise results for DELAWARE II (89-03), survey of apex predators - sharks. Jack Casey, NMFS Narragansett Laboratory cruise report, 9 p.

[4] Cruise results for DELAWARE II (91-06), survey of apex predators - sharks. Jack Casey, NMFS Narragansett Laboratory cruise report, 12 p.

[5] Cruise results for OREGON II 95-04 (218), coastal shark assessment. Mark Grace, NMFS Mississippi Laboratories cruise report, 19 p.

[6] Cruise results for OREGON II 96-04 (222), coastal shark assessment. Mark Grace, NMFS Mississippi Laboratories cruise report, 12 p.

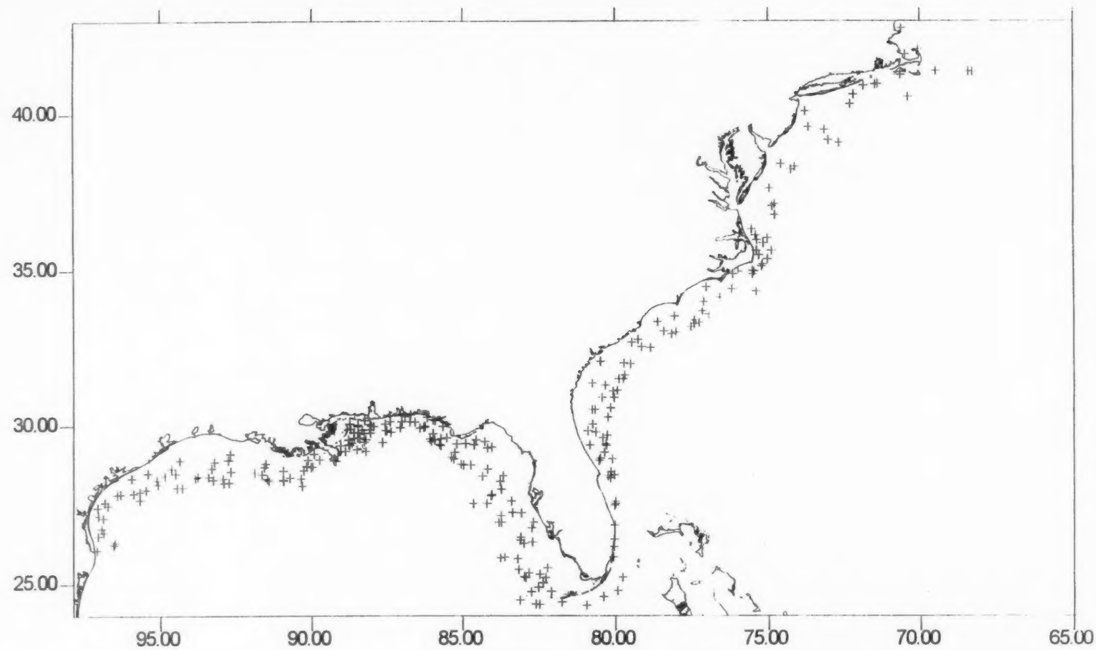


Figure 1. — Longline station locations for NMFS shark longline pilot studies, 1995–1996.

and Musick, 1994) indicated that monofilament gear is significantly more efficient. The longline consisted of 1.0 n.mi. of 940-lb (426 kg) test monofilament mainline, 100 baited (*Scomber scomber*) #3/0 shark hooks with 12-ft (3.66 m) gangions of 730-lb (332 kg) test monofilament (3.66 m). A hydraulic longline reel was used for setting and retrieving the mainline. Radar high-flyers with strobes and bullet buoys were used to mark longline locations. The mainline was weighted at the start buoy, midset, and end buoy; additional weights were added (between start and midset, between midset, and end) for sites in areas of strong currents.

Effort was primarily bottom longline, but nine experimental pelagic longline sets were included in the 1996 project. Unfortunately, the pelagic sets failed to capture sharks and effort for these experimental stations were excluded from all subsequent analyses.

During the Gulf of Mexico 1995 survey, approximately 750 hooks were baited with other bait (shark pieces and finfish pieces) since the bait supply was not adequate to complete the survey. Differences in shark catches as related to bait type during the Gulf of Mexico 1995 survey were not statistically evaluated due to the small sample size and our inability to address the effects of other variables such as location, depth, and time of day. Effort and catch for hooks with other bait were included in data analyses.

All sharks captured during the surveys were identified and most were tagged and released. Selected shark species were brought aboard for collection of biological data. Specimens collected were for scientific uses that included DNA analysis, ecto- and endoparasites, tooth morphology, reproductive biology, and vertebrae for age and growth. The volume of specimens landed depended upon the objectives of cruise participants, and landing of sharks for scientific purposes was less than 10% of all live specimens captured; sharks landed dead were generally sampled. Sharks landed for biological sampling were primarily U.S. shark management plan species (Table 1).

Biological data for all sharks captured included identifications (genus and species), length (mm), weight (kg), sex, and mortality. Length measurements were fork length and total length and were either actual or estimated (sharks not landed or measurement not recorded). Some lengths or weights were derived with conversion factors using a known variable (length or weight). Exceptions were for those sharks too large to land or for those that escaped; estimating both length and weight was then necessary. During the 1996 project, a section of the ship's rub rail 1.5 m above waterline was marked in 0.25 m, 0.50 m, and 1.0 m increments (up to 4.0 m) to facilitate length estimates for sharks brought alongside ship. Estimated lengths and weights were identified in survey data and were included with summary information presented for each species.

Research Platforms

Two research vessels were used during the 1995 and 1996 surveys. The research platform for the Gulf of Mexico

Table 1. — Management units for sharks of the Atlantic and Gulf of Mexico (NOAA, 1993).

Species and management unit	
Large Coastal Sharks	
Sandbar	*Carcharhinus plumbeus*
Blacktip	*Carcharhinus limbatus*
Dusky	*Carcharhinus obscurus*
Spinner	*Carcharhinus brevipinna*
Silky	*Carcharhinus falciformis*
Bull	*Carcharhinus leucas*
Bignose	*Carcharhinus altimus*
Narrowtooth	*Carcharhinus brachyurus*
Galapagos	*Carcharhinus galapagensis*
Night	*Carcharhinus signatus*
Caribbean reef	*Carcharhinus perezi*
Tiger	*Galeocerdo cuvieri*
Lemon	*Negaprion brevirostris*
Sand tiger	*Odontaspis taurus*
Bigeye sand tiger	*Odontaspis noronhai*
Nurse	*Ginglymostoma cirratum*
Scalloped hammerhead	*Sphyrna lewini*
Great hammerhead	*Sphyrna mokarran*
Smooth hammerhead	*Sphyrna zygaena*
Whale	*Rhincodon typus*
Basking	*Cetorhinus maximus*
White	*Carcharodon carcharias*
Small Coastal Sharks	
Atlantic sharpnose	*Rhizoprionodon terraenovae*
Caribbean sharpnose	*Rhizoprionodon porosus*
Finetooth	*Carcharhinus isodon*
Blacknose	*Carcharhinus acronotus*
Smalltail	*Carcharhinus porosus*
Bonnethead	*Sphyrna tiburo*
Atlantic angel	*Squatina dumerili*
Pelagic Sharks	
Shortfin mako	*Isurus oxyrinchus*
Longfin mako	*Isurus paucus*
Porbeagle	*Lamna nasus*
Thresher	*Alopias vulpinus*
Bigeye thresher	*Alopias superciliousus*
Blue	*Prionace glauca*
Whitetip	*Carcharhinus longimanus*
Sevengill	*Heptranchias perlo*
Sixgill	*Hexanchus griseus*
Bigeye sixgill	*Hexanchus vitulus*

Table 2. — Total number of captures, catch per unit effort (CPUE, captures/100 hook hours), standard deviation of the mean (STD), standard error of the mean (STDERR), and coefficient of variation of the mean (VC) for sharks encountered during NMFS 1995 and 1996 shark pilot studies.

Shark species	Captures	CPUE	STD	STDERR	CV
1995 NMFS Shark Pilot Study (n = 127)					
Blacknose	18	0.142	0.545	0.048	0.341
Spinner	7	0.055	0.341	0.030	0.548
Silky	6	0.047	0.278	0.025	0.521
Finetooth	4	0.032	0.355	0.032	1.000
Bull	6	0.047	0.305	0.027	0.573
Blacktip	26	0.205	0.749	0.066	0.325
Dusky	1	0.008	0.089	0.008	1.000
Sandbar	30	0.236	0.684	0.061	0.257
Tiger	65	0.512	1.119	0.099	0.194
Nurse	6	0.047	0.213	0.019	0.400
Smooth dogfish	8	0.063	0.484	0.043	0.682
Sand tiger	1	0.008	0.089	0.008	1.000
Atlantic sharpnose	258	2.032	3.593	0.319	0.157
Scalloped hammerhead	10	0.079	0.298	0.026	0.336
Great hammerhead	9	0.071	0.338	0.030	0.422
1996 NMFS Shark Pilot Study (n = 142)					
Bignose	1	0.007	0.084	0.007	1.000
Blacknose	40	0.282	1.020	0.086	0.304
Spinner	5	0.035	0.220	0.018	0.524
Silky	2	0.014	0.118	0.010	0.705
Bull	2	0.014	0.118	0.010	0.705
Blacktip	17	0.120	0.469	0.039	0.328
Dusky	2	0.014	0.118	0.010	0.705
Sandbar	18	0.127	0.410	0.034	0.271
Tiger	10	0.070	0.283	0.024	0.337
Nurse	3	0.021	0.144	0.012	0.573
Smooth dogfish	5	0.035	0.220	0.018	0.524
Sand tiger	2	0.014	0.118	0.010	0.705
Atlantic sharpnose	288	2.028	5.338	0.448	0.221
Scalloped hammerhead	7	0.049	0.217	0.018	0.370
Great hammerhead	6	0.042	0.234	0.020	0.466
Spiny dogfish	16	0.113	0.745	0.062	0.555

1995 and the entire 1996 survey was the NOAA Ship *Oregon II* (R332). Vessel specifications are: 170 ft (51.8 m) length, 34 ft (10.4 m) width, 14 ft (4.3 m) draft when fully fueled, displacement of 952 tons, accommodates 31 (13 scientists).

The research platform for the U.S. east coast 1995 survey was the NOAA Ship *Relentless* (R335). Vessel specifications are: 224 ft (68.3 m) length, 43 ft (13.1 m) width, 15 ft (4.6 m) draft when fully fueled, displacement of 2,300 tons, accommodates 42 (20 scientists).

Oceanographic and Meteorological Data

Oceanographic data were collected with a CTD unit deployed at depth. The CTD was hardwired to a ship's computer for data archival. Data elements included water temperature (Celsius), dissolved oxygen (mg/l), salinity (ppt), fluorometer (chlorophyll, mg/l), transmissivity (turbidity), and depth (m). Dissolved oxygen, salinity, and temperature recorded by the CTD were verified daily by comparison with measurements from an oxygen meter, refractometer, and thermometer. During the Atlantic 1995 survey, only temperature and salinity data were collected due to a CTD malfunction.

Meteorological data were collected hourly and recorded in the ship's weather log and on survey station sheets. Observations included air temperature, barometric pressure, wind speed and direction, and sea state.

Results and Discussion

During 78 survey days, 269 bottom longline and 9 pelagic longline sets were completed. A total of 879 sharks representing 17 species (Table 2) were captured in coastal waters from Brownsville, Tex., to Cape Ann, Mass. (Fig. 2) during the NMFS 1995 and 1996 pilot studies. Twelve of the 22 species classified in the fishery management plan (NOAA, 1993) as large coastal sharks were encountered. Also captured were 3 of 7 species classified as small coastal sharks and 2 other small sharks not classified as small coastals (*Mustelus canis* and *Squalus acanthias*). Of the sharks captured, 66% (330 small coastal sharks and 246 large coastal sharks) were tagged and released.

The Atlantic sharpnose shark, *Rhizoprionodon terraenovae*, was the most commonly encountered species over the geographic range of this study with 546 captures. This species occurred throughout the Gulf of Mexico and eastern seaboard except north of Chesapeake Bay where the spiny dogfish, *Squalus acanthias*, replaced it as the dominant small coastal shark species. The second most abundant species encountered was the tiger shark, *Galeocerdo cuvieri*, with 75 captures from as far west as Texas in the Gulf of Mexico to as far north as the Chesapeake Bay in the western North Atlantic. The blacknose shark, *Carcharhinus acronotus*, another small coastal species, was the third most abundant shark with 58 captures, all from the Gulf of Mexico. The fourth and fifth most abundant species, the sandbar shark, *C. plumbeus*, and the blacktip

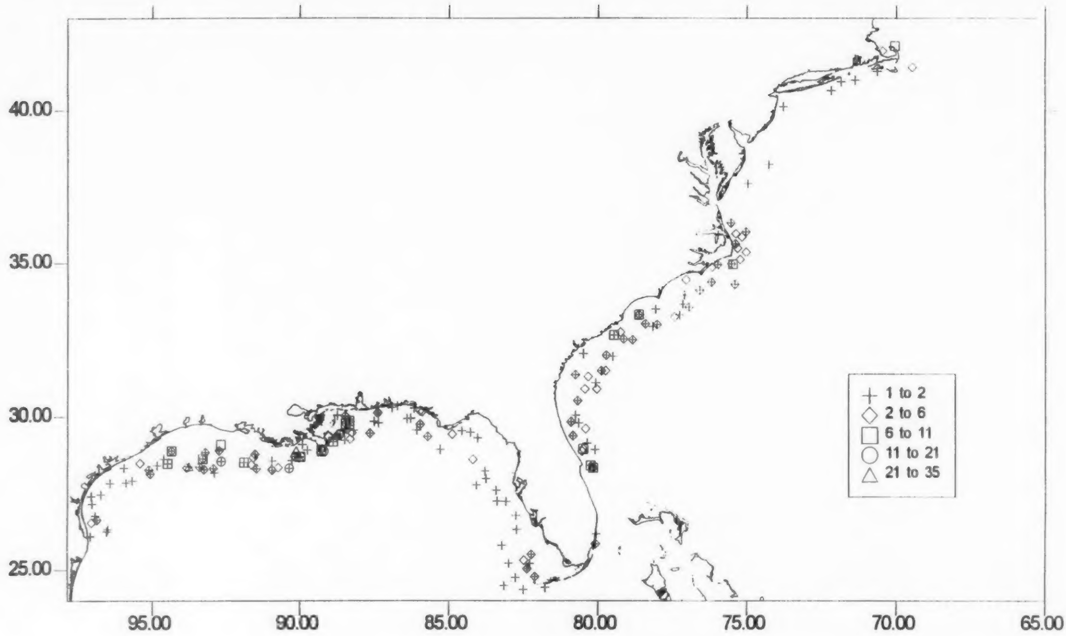


Figure 2. — Locations of shark captures for NMFS shark longline pilot studies, 1995–1996.

shark, *C. limbatus*, are the primary target species of directed shark fisheries. Sandbars were captured throughout the geographic range of this study from just north of Brownsville, Tex. to just south of Cape Ann, Mass. Blacktips were captured in the north-central Gulf of Mexico and in tropical waters of southern Florida, but were not encountered throughout most of their known range along the eastern seaboard.

Most species of sharks were captured during both day and night (Table 3) suggesting that the commercial practice of fishing only at night is not a requirement for catching sharks. It is possible that some species are more vulnerable to capture at night, but significant differences in catch rates are not evident from the relatively small samples. Provided this survey is continued, differences in catch rates with time of day will be detected if such differences exist.

During the pilot studies, 24 incidental non-shark species were captured (Table 4). Banded eels, *Ophichthus rex*, were the most frequently caught incidental species with 44 captures, followed by great barracuda, *Sphyraena barracuda* — 36 captures, roughtail stingray, *Dasyatis centroura* — 25 captures, and red grouper, *Epinephelus morio* — 17 captures. During the 1996 project, one swordfish, *Xiphias gladius*, was captured during an experimental pelagic longline set. Incidental captures comprised 17% of the total captures (1,065) for all surveys combined and incidental captures occurred in most survey areas.

Species Profiles

Small Coastal Sharks

Small coastal sharks comprised 72% of all shark captures. Of 7 small coastal shark species managed under the 1993 shark FMP, 3 species were captured during the 1995 and 1996 surveys.

Blacknose shark,
Carcharhinus acronotus

Blacknose sharks were captured only in the Gulf of Mexico (58 captures).

Table 3. — Mean shark catch rates by 6-hour time periods during NMFS 1995 and 1996 shark pilot studies.

Species	Day[1] $n = 66$	Dusk $n = 77$	Night $n = 61$	Morning $n = 65$
Blacknose	0.152	0.117	0.262	0.354
Finetooth	0.0	0.0	0.0	0.062
Atlantic sharpnose	1.182	1.675	2.525	2.846
Bignose	0.0	0.013	0.0	0.0
Spinner	0.030	0.039	0.066	0.046
Silky	0.030	0.052	0.0	0.031
Bull	0.045	0.013	0.049	0.015
Blacktip	0.212	0.065	0.131	0.246
Dusky	0.030	0.013	0.0	0.0
Sandbar	0.106	0.130	0.295	0.200
Tiger	0.348	0.195	0.213	0.369
Nurse	0.015	0.039	0.049	0.031
Sand tiger	0.0	0.0	0.033	0.015
Scalloped hammerhead	0.045	0.078	0.033	0.092
Great hammerhead	0.015	0.052	0.098	0.062
Smooth dogfish	0.0	0.0	0.164	0.464
Spiny dogfish	0.030	0.104	0.016	0.077

[1] Day 10am–4pm, Dusk 4pm–10pm, Night 10pm–4am, Morning 4am–10am.

Blacknose sharks were distributed from south of Galveston Bay, Tex., to the Dry Tortugas, Fla., with most captures from the vicinity of the eastern slope of the Mississippi River Delta. Captures occurred in all depth strata but only 2 of the 58 captures were in depths >25 fm. Total lengths ranged from 795 to 1270 mm.

Finetooth shark, *C. isodon*

Finetooth sharks were captured only during the 1995 Gulf of Mexico survey (4 captures), and all captures occurred in the vicinity of the southwest pass of the Mississippi River in the 20–30 fm depth strata. Total lengths ranged from 1,117 to 1,440 mm.

Atlantic sharpnose shark, *Rhizoprinodon terranovae*

Atlantic sharpnose sharks were captured during all surveys (546 captures). Distribution in the Atlantic was from Cape Canaveral, Fla., to Chesapeake Bay, Va. In the Gulf of Mexico, distribution was fairly uniform except from Cape San Blas, Fla., to west of Tampa Bay, Fla., where no captures were recorded. Captures occurred in all depth strata. Total lengths ranged from 439 to 1,200 mm.

Large Coastal Sharks

Large coastal sharks comprised 28% of all sharks captured during the pilot studies. Twelve of the 22 large coastal shark species managed under the 1993 shark FMP were captured.

Bignose shark, *C. altimus*

One bignose shark, a female, was captured during the 1996 Atlantic survey off the New Jersey coast in a depth of 25 fm. The total length was 1,293 mm and weight was 28 kg. This capture is considerably north of the known range (Compagno, 1984). Confirmation of this capture was by subsequent examination of tooth morphology and counts (Hubbell[7]).

Spinner shark, *C. brevipinna*

Spinner sharks were captured only in the Gulf of Mexico (12 captures), and were distributed primarily in the vicinity of the Mississippi River Delta with additional captures south of Destin, Fla. (1) and just north of the Dry Tortugas, Fla. (1). Captures occurred in all depth strata. Total lengths ranged from 850 to 1,720 mm.

Silky shark, *C. falciformis*

Silky sharks were captured only in the Gulf of Mexico (8 captures). They were distributed in two areas: from the U.S.–Mexico border to Galveston Bay, Tex., and additional captures just north of the Dry Tortugas, Fla. Captures occurred in all depth strata. Total lengths ranged from 770 to 2,120 mm.

Bull shark, *C. leucas*

Bull sharks were captured only in the Gulf of Mexico (8 captures). They were encountered in all depth strata and were captured from south of Galveston Bay, Tex., to south of Mobile Bay, Ala. Total lengths ranged from 1,830 to 2,987 mm.

Blacktip shark, *C. limbatus*

Blacktip sharks were captured in both the Gulf of Mexico and western North Atlantic (43 captures). They were distributed in the Gulf of Mexico from south of Galveston Bay, Tex., to south of Mobile Bay, Ala., and along the western Florida shelf from Naples, Fla., to the Dry Tortugas. In the Atlantic, distribution was along the east Florida shelf from Miami to West Palm Beach. Captures occurred in all depth strata. Total lengths ranged from 880 to 2,000 mm, but specimens with fork lengths less than 1,266 mm occurred only in depths less than 15 fm.

Dusky shark, *C. obscurus*

Dusky sharks were captured off the eastern seaboard and in the Gulf of Mexico (3 captures). The areas of dusky shark captures were east of Corpus Christi, Tex., southwest of the Dry Tortugas, Fla., and east of Charleston, S.C. Captures occurred in the 30–40 fm

Table 4. — Incidental catch mean catch rates for NMFS 1995 and 1996 shark pilot studies.

Species	Atlantic 1995 $n = 45$	Atlantic 1996 $n = 56$	Gulf 1995 $n = 82$	Gulf 1996 $n = 86$	Combined (# captured) $n = 269$
Roughtail stingray *Dasyatis centroura*	.133	.196		.093	.093 (25)
Gafftop catfish *Bagre marinus*	.022				.004 (1)
Great barracuda *Sphyraena barracuda*	.200	.018	.134	.174	.134 (36)
Jewfish *Epinephelus itajara*	.022				.004 (1)
Scamp *Mycteroperca phenax*	.022				.004 (1)
Cobia *Rachycentron canadum*	.044	.018	.024		.015 (4)
Clearnose skate *Raja eglanteria*		.054		.058	.030 (8)
Rosette skate *Raja garmani*		.180			.037 (10)
Atlantic cod *Gadus morhua*		.018			.004 (1)
Red Grouper *Epinephelus morio*		.018	.122	.070	.063 (17)
Gag grouper *Mycteroperca microlepis*		.018			.004 (1)
Bluefish *Pomatomus saltatrix*		.125			.026 (7)
Remora *Echeneis naucrates*		.018			.011 (3)
Amberjack *Seriola dumerili*		.018		.012	.007 (2)
Wrymouth *Crytacanthodes maculatus*		.036			.007 (2)
Devil ray *Mobula hypostoma*			.024		.007 (2)
Cownose ray *Rhinoptera bonasus*			.085		.026 (7)
Banded eel *Ophichthus rex*			.280	.244	.164 (44)
Red snapper *Lutjanus campechanus*			.073	.023	.030 (8)
Atlantic bonito *Sarda sarda*			.012		.004 (1)
Cusk eel *Lepophidium* sp.			.024		.007 (2)
Southern stingray *Dasyatis americana*				.012	.004 (1)
Wahoo *Acanthocybium solandri*				.012	.004 (1)
Swordfish *Xiphias gladius*				.012	.044 (1)

[7] Hubbel, Gordon. Key Biscayne, Fla. Personal commun.

depth strata. Total lengths ranged from 2,200 mm to 2,980 mm.

Sandbar shark, *C. plumbeus*

Sandbar sharks, captured during all Atlantic and Gulf of Mexico surveys (48 captures), were distributed in the Atlantic east of Miami to Cape Canaveral, Fla., from the Georgia–South Carolina area to Cape Hatteras, east of the Delmarva peninsula and south of the eastern end of Long Island, N.Y. In the Gulf of Mexico, distribution was fairly uniform, and captures occurred in all depth strata. Total lengths ranged from 1,060 to 2,437 mm. In the Atlantic, all specimens with total lengths <1,649 mm (converted by FL = (0.8175)TL + 2.5675 (Kohler et al., 1996)) were captured in depths <15 fm.

Tiger shark, *Galeocerdo cuvieri*

Tiger sharks were captured during all Atlantic and Gulf of Mexico surveys (75 captures), with total lengths ranging from 760 to 3,356 mm and captures occurring in all depth strata. In the Atlantic, tiger sharks were distributed from north Florida to Cape Hatteras with an additional capture close to Miami, Fla. In the Gulf of Mexico, distribution was from the eastern slope of the Mississippi River Delta to west of Tampa Bay, Fla., with additional captures between Galveston Bay, Tex., to south of western Louisiana.

Nurse shark, *Ginglymostoma cirratum*

Nurse sharks were captured during the Atlantic 1995 and Gulf of Mexico 1995 and 1996 surveys (9 captures). Distribution in the Atlantic was from east of New Smyrna Beach, Fla., to Charleston, S.C., and in the Gulf of Mexico from south of Pensacola, Fla., and west of Clearwater, Fla., to the Dry Tortugas, Fla. Captures in the Atlantic occurred in the 10–20 fm depth strata; in the Gulf of Mexico captures occurred in all depth strata. Total lengths ranged from 1,820 to 3,040 mm.

Sand tiger shark, *Odontapspis taurus*

Sand tiger sharks were captured during the Atlantic 1995 and 1996 and the Gulf of Mexico 1996 surveys (3 captures). Distribution in the Atlantic was between Cape Hatteras, N.C., and Chesapeake Bay, Va., and the Gulf of Mexico capture was from south of Destin, Fla. Captures occurred in the 10–20 fm and 30–40 fm depth strata. Total lengths ranged from 1,800 to 2,199 mm.

Scalloped hammerhead shark, *Sphyrna lewini*

Scalloped hammerhead sharks were captured during all surveys (17 captures). Distribution in the Atlantic was off Cape Canaveral, Fla., and Cape Fear, N.C., and in the Gulf of Mexico distribution was from south of Galveston Bay, Tex., to south of Mobile Bay, Ala., off Cape San Blas, Fla., and south of the lower Florida Keys. Captures occurred in all depth strata, and total lengths ranged from 1,010 to 2,882 mm.

Great hammerhead shark, *S. mokarran*

Great hammerhead sharks were captured during all surveys (15 captures). Distribution in the Atlantic was from Cape Canaveral, Fla., to Cape Hatteras, N.C., and in the Gulf of Mexico from south of Galveston Bay, Tex., to south of western Louisiana, south of Pensacola, Fla., to south of Panama City, Fla., and just north of the Dry Tortugas, Fla. Captures occurred in depth strata less than 30 fm, and total lengths ranged from 1,974 to 3,048 mm.

Other Sharks

Smooth dogfish, *Mustelus canis*

Smooth dogfish were captured during the Atlantic 1996 and Gulf of Mexico 1995 and 1996 surveys (13 captures). Distribution in the Atlantic was east of New Jersey and south of Martha's Vineyard, Mass., and in the Gulf of Mexico from south of western Louisiana to south of Cape San Blas, Fla. Captures in the Atlantic occurred in the 10–20 fm depth strata, and in the Gulf of Mexico in the 30–40 fm depth strata. Total lengths ranged from 560 to 1,280 mm.

Spiny dogfish, *Squalus acanthias*

Spiny dogfish were only captured during the Atlantic 1996 survey (16 captures). They were distributed from the east tip of Long Island, N.Y., southeast and north of Cape Cod, Mass., and within Cape Cod Bay, Mass. Captures occurred in all depth strata, and total lengths ranged from 600 to 970 mm.

Species Profiles for Sharks Not Captured

The lack of captures for some species can be explained by considering the habitats and distributions of each species and by comparing the NMFS pilot study longline data with data summarized by Branstetter[8] and NMFS SEAMAP bottom trawling survey data (1972 to 1996). The Branstetter[8] commercial shark longline fishery catch summaries reports 7,836 large coastal shark captures and 3,037 small coastal shark captures from specific areas in the eastern Gulf of Mexico and the U.S. Atlantic coast from Florida north to Cape Hatteras, N.C. (1994 and 1995). The NMFS SEAMAP surveys (Table 5) represent Gulf of Mexico effort from 3,712 bottom trawling tows (Texas-Mexico border to Alabama).

Small Coastal Sharks

Smalltail shark, *C. porosus*

Smalltail sharks were not captured but are distributed from inshore estuaries and coastal areas to 18 fm (Compagno, 1984). NMFS SEAMAP trawl data reports 2 smalltail shark captures, which verifies their presence in the survey area. Branstetter[8] reported no captures of this species from commercial shark vessels, which leads to speculation that either the species is relatively rare, longline gear may not efficiently sample this species, or that survey sampling depths which were deeper than 10 fm may be outside of the primary range for smalltail sharks.

Caribbean sharpnose, *R. porosus*

The Caribbean sharpnose is the only small coastal shark that occurs primarily outside of the survey area (Com-

[8] Branstetter, S. 1996. Characterization and comparisons of the directed commercial shark fishery in the eastern Gulf of Mexico and off North Carolina through an observer program. Gulf and South Atlantic Fisheries Development Foundation, Inc. Marfin award NA57FF0286, Final rep., 41 p.

pagno, 1984). Based on the known Caribbean distribution of this species, captures were not expected during the pilot studies. Branstetter[8] and NMFS SEAMAP trawl surveys did not report any Caribbean sharpnose captures.

Bonnethead shark, *S. tiburo*

Bonnethead sharks were not captured but are distributed from inshore estuaries and coastal areas to 44 fm (Compagno, 1984). Based on NMFS SEAMAP trawl data, bonnetheads are the second most commonly caught sharks with 830 captures; Branstetter[8] reports 16 bonnethead captures. The lack of bonnethead captures may be due to the low number of nearshore sampling sites occupied during these pilot surveys or inefficiency of longline gear for capturing this species.

Angel shark, *Squatina dumerili*

Angel sharks are coastal residents to depths of 760 fm (Compagno, 1984). They were lacking from the longline catches, and apparently are rare in commercial catches as well (Branstetter,[8] 0 captures), although their distribution is known to be within survey depths. A total of 59 angel sharks were captured during NMFS SEAMAP trawl surveys, so the species is present within the survey area. Fisheries for angel shark species in various parts of the world exist, but these fisheries generally employ gill nets or bottom trawls (Bonfil, 1994). Gear selectivity is probably responsible for the lack of angel shark captures in these longline surveys.

Table 5. — NMFS/SEAMAP trawl catch summary for sharks captured during Gulf of Mexico suveys, 1972–96; catches adjusted to a 60-minute tow.

Species	Captures	Weight (kg)	Frequency of occurence	% frequency of occurence
Atlantic sharpnose	4,197	5,199	732	12.3
Bonnethead	830	1,519	201	3.4
Smooth dogfish, *Mustelus canis*	134	344	59	1.0
Florida smoothhound, *Mustelus norrisi*	121	291	36	0.6
Carcharhinidae	85	99	12	0.2
Blacknose	81	226	29	0.5
Angel shark	59	159	23	0.4
Carcharhinus sp.	56	109	13	0.2
Silky	44	68	8	0.1
Blacktip	35	137	11	0.2
Scalloped hammerhead	13	20	5	0.1
Great hammerhead	9	219	4	0.1
Mustelus sp.	8	21	4	0.1
Sphyrna sp.	7	2	3	0.1
Bull	4	182	2	0.0
Chain dogfish, *Scyliorhinus retifer*	3	0.1	2	0.0
Nurse	3	3	2	0.0
Spinner	2	69	1	0.0
Dusky	2	4	1	0.0
Smalltail	2	8	1	0.0
Sphyrnidae	2	9	1	0.0

Large Coastal Sharks

For the large coastal shark species not captured, the narrowtooth, *C. brachyurus*; bigeye sand tiger, *Odontaspsis noronhai*; reef, *C. perezi*; and galapagos sharks, *C. galapagensis*, are generally distributed outside of the survey areas or are rare. Whale sharks, *Rhincodon typus*; and basking sharks, *Cetorhinus maximus*, are filter feeders and, except for accidental entanglement, would not be a component of longline catches.

White shark, *Carcharodon carcharias*

White sharks are distributed within the survey area (Compagno, 1984), but none were captured. Branstetter[8] reports 2 white shark captures; there were no white shark captures reported during NMFS SEAMAP trawl surveys. The lack of white shark captures may be due to low sampling densities, or the species may be uncommon in the depths and temperatures (Compagno, 1984) of survey sites.

Night shark, *Carcharhinus signatus*

No night sharks were encountered during these surveys although their distribution can be from 14 fm (Bigelow and Schroeder, 1948) to 328 fm (Raschi et al., 1982). Raschi et al. (1982) summarized the general distribution as between 109 fm to 328 fm. Survey depths sampled may be outside of the primary depth range for night sharks, and the species may be relatively rare in shallower waters. Branstetter[8] reports 2 night shark captures; there were no night shark captures reported during NMFS SEAMAP trawl surveys.

Lemon shark, *Negaprion brevirostris*

Lemon sharks were not captured even though they are distributed within depths less than 50 fm (Compagno, 1984). Castro (1983) refers to them as a "common coastal shark" and Compagno (1984) indicates these sharks occur in a variety of inshore and coastal habitats. The lack of survey sites inside of 10 fm may be the primary reason for no catch of this species. Branstetter[8] reports 78 lemon shark captures with 91% of those captures from the west Florida shelf. The shelf in this area of the Gulf of Mexico is very broad and NMFS survey sites were generally well offshore. No lemon shark captures were reported by NMFS SEAMAP trawl surveys.

Smooth hammerhead shark, *Sphyrna zygaena*

Distribution of the smooth hammerhead shark is coastal to offshore (Compagno, 1984). Branstetter[8] reported 5 smooth hammerhead captures; there were no smooth hammerhead captures reported during NMFS SEAMAP trawl surveys. Lack of smooth hammerhead captures may be due to low sampling densities or the species may simply be uncommon in the depths sampled.

Environmental Data

Dissolved oxygen levels at survey sites ranged from 0.0 to 8.5 mg/l; the CTD dissolved oxygen meter is accurate to within 0.5 mg/l dissolved oxygen and levels were compared daily with a YSI oxygen meter. Dissolved oxygen levels associated with shark captures ranged from 0.0 to 7.8 mg/l (Table 6). The lowest oxygen levels were generally from maximum sampling depths near sea bottom. Recent laboratory experiments by Parsons and Carlson[9] indicate oxygen levels below

[9] Parsons, G., and J. Carlson. Behavioral and physiological responses to hypoxia in the bonnethead shark, *Sphyrna tiburo*. Dep. Biol., Univ. Miss., Oxford. Unpul. manuscr., 30 p.

Table 6. — Dissolved oxygen, temperature and salinity values associated with shark captures during NMFS 1995–96 shark longline pilot studies.

Species	Dissolved oxygen (mg/l)	Temperature (°C)	Salinity (‰)
Blacknose	3.0–6.7	20.0–30.0	32.8–36.8
Finetooth	3.9	25.8	34.9
Atlantic sharpnose	0.2–7.5	18.0–30.0	32.4–36.4
Bignose	7.5	8.0	32.3
Spinner	3.0–7.3	20.0–26.0	34.9–35.1
Silky	4.3–6.6	18.8–26.2	35.9–36.4
Bull	3.1–5.9	22.5–30.0	33.6–36.0
Blacktip	0.0–7.0	17.5–30.0	27.0–36.0
Dusky	4.9–5.5	21.0–25.0	36.3–36.4
Sandbar	3.4–6.8	10.5–28.5	31.6–36.4
Tiger	3.6–6.4	17.0–29.0	32.4–36.6
Nurse	5.3–7.4	22.5–28.5	35.4–36.4
Sand tiger	3.9–6.2	18.0–24.0	32.0–36.0
Scalloped hammerhead	2.5–7.4	7.5–27.5	32.4–36.4
Great hammerhead	3.2–6.7	13.5–28.5	34.3–36.3
Smooth dogfish	3.5–6.5	15.0–22.5	31.5–36.0
Spiny dogfish	6.5–7.8	9.6–12.0	31.5–32.1

3.5 mg/l create physiological stress for bonnethead sharks (increased mouth gape and swimming speed). Renaud (1986) considered hypoxia (<2.0 mg/l) to be a barrier affecting distribution of finfish and crustaceans off southern Louisiana. There were 22 longline sites in hypoxic areas with oxygen concentrations ≤3.5 mg/l. The mean shark catch rate from these sites was 4.9 shark captures/100 hook hours (4.0/100 hook hours for small coastals and 0.9/100 hook hours for large coastals) with eight shark species captured: Atlantic sharpnose, blacknose, smooth dogfish, spinner, blacktip, bull scalloped hammerhead, and great hammerhead. Shark captures in hypoxic areas may be attributable to gear fishing above near-bottom hypoxic zones or from attraction to the baited longline.

Bottom temperatures ranged from 6.8°C to 31°C with sharks captured at most temperatures within this range (Table 6). Bottom temperatures in the Gulf of Mexico and along the eastern seaboard south of Cape Hatteras, N.C., were generally between 18 and 31°C; bottom temperatures north of Cape Hatteras ranged from 6.8 to 18°C. Atlantic sharpnose, blacknose, blacktip, and bull sharks were the only sharks captured from longline sets with bottom temperatures above 30°C; a bignose shark, scalloped hammerheads, and spiny dogfish were the only sharks captured from longline sets with bottom temperatures below 10°C.

Station salinities ranged from 26.7 to 36.8‰ and sharks were captured throughout this range (Table 6). Blacktips, sandbars, smooth dogfish, and spiny dogfish were the only sharks captured from longline sets with bottom salinities less than 32 ‰; blacktip sharks were the only sharks captured from longline sets with salinities less than 30‰.

Precision of Estimates

These surveys demonstrated that populations of many shark species can be sampled using longline gear and random sampling design, but the fundamental question in terms of fishery management is whether these surveys can be used for stock assessments. From a management perspective, the primary objective was to develop a method for tracking year-to-year variations in abundance for as many species as practical, therefore, the surveys were designed to satisfy the following five principles: stockwide survey, synopticity, well defined sampling universe, controlling biases, and useful precision.

The stockwide survey principle can be difficult to achieve with large and active species; for multispecies complexes it is usually not feasible to cover the complete range of all species. If the survey area is too small compared to the full range of a stock, year-to-year variation may be dominated by local immigrations and emigrations, and thus of little use for assessment. The surveys were designed to cover the 10–40 fm depth range over as large a geographical area as possible given a general distributional knowledge of most of the species encountered. A survey along the Mexico coast of the Gulf of Mexico was planned for 1997 to extend stockwide coverage for Gulf of Mexico species and those species that possibly migrate between the Gulf of Mexico and western North Atlantic.

Synopticity, the idea of a survey as a snapshot in time, is probably not a restrictive issue in the current survey development. Populations and distributions of adult sharks are probably not changing rapidly over the course of these surveys. This could be a problem if surveys were conducted during spring and fall when distributions are likely to change considerably.

Defining the sampling universe will not be complex once decisions regarding species range distributions have been made. Controlling bias is related to options for survey operations and bias for this study can be defined as anything that might produce a catch per unit effort (CPUE) not proportional to abundance.

Probably the most useful measure of precision is the coefficient of variation of the mean (CV), defined as the standard error of the mean over the mean. The CV of the mean expresses uncertainty as a potential percentage change of a population. For each shark species encountered, the total number of captures, the mean CPUE (catch/100 hook hours), standard deviation of the mean, the standard error of the mean, and the CV of the mean are presented by survey year in Table 2.

For species that have been subjected to heavy fishing pressure for at least 2 decades and that must be considered depleted over parts, if not all, of their range, CV's of less than 0.40 may fall within reasonable expectations. If that is an acceptable criterion, these surveys are providing estimates with adequate precision for Atlantic sharpnose, tiger, sandbar, blacktip, blacknose, and scalloped hammerhead sharks. Of these species, the sandbar and blacktip sharks are of particular management concern because they are the primary targets of the U.S. commercial shark fishery.

Conclusions

After 2 years of this pilot study, it is possible to draw some conclusions regarding the efficacy of this approach for determining distribution and abundance of coastal shark species. The pilot study shark catches, summarized across years from offshore Brownsville, Tex. to Cape Ann, Mass., were very close to those reported by Branstetter[8] for commercial activities on major fishing grounds in the eastern Gulf of Mexico and western North Atlantic. This suggests that a 1-mile, 100-hook bottom longline fished for 1 hour at randomly selected locations produces similar catch rates to what might be expected in a commercial fishing operation.

Sharks encountered during this study were of similar size to those reported

from commercial landings (Branstetter[8]). This implies that the surveys were sampling the same age and size groups of sharks targeted by commercial operations. This is an important consideration when attempting to compare this survey information with observer data from commercial vessels. It is also of importance when evaluating shark distributions and abundance since the range of commercially important species often extends well beyond geographic boundaries of primary fishing grounds. By determining catch rates and landings in heavily fished areas, it may be possible to develop minimum estimates for areas outside the fishing grounds where fishing mortality rates are lower. Continuation of observer programs in conjunction with fishery independent surveys should provide a good means of monitoring the status of populations over their entire ranges, and not just mortalities for primary fishing grounds.

Size ranges for each shark species encountered during the pilot studies included minimum sizes at maturity for males or females (Table 7). This indicates that a portion of the potential spawning stock of most shark species was sampled. Continued development of time series will be useful for monitoring changes in spawning stock complexity (number, sex ratios, and distribution).

Due to small sample sizes for most of the shark species encountered, any differences in species composition and CPUE by depth are not detectable. However, of the commonly encountered shark species (>10 captures), there was little change for species composition and CPUE values over the 3 sampling depth strata. This is probably because the depth distribution range of most coastal species is more extensive than the 10–40 fm depth range of the surveys.

Examination of the CV of the mean by species suggests the survey provides reasonably precise estimates for 6 species of sharks. For the remainder of shark species encountered, CV's indicated very imprecise estimates. In addition, CV's for any species of interest can be improved by altering the sampling design to increase sampling in areas or depths where target species are most abundant.

Table 7. — Genus and species, number of captures (No.) and total length (mm) size ranges for sharks encountered during NMFS 1995 and 1996 pilot studies and minimum sizes for males and females.

Species	No.	Total length size range (mm)	Minimum total length maturity for males and females
Blacknose	58	795–1270	Males 970 mm, Females 1030 mm Compagno (1984)
Finetooth	4	1117–1440	Males 1300 mm, Females 1350 mm Castro (1993)
Atlantic sharpnose	546	439–1200	Males 800 mm, Females 850 mm Parsons (1985)
Bignose	1	1293	Males 2160 mm, Females 2260 mm Compagno (1984)
Spinner	12	850–1720	Males 1700 mm, Females 1800 mm Branstetter (1987a)
Silky	4	700–2120	Males 2100 mm, Females 2200 mm Branstetter (1987b)
Bull	8	1830–2987	Males 2100 mm, Females 2250 mm Branstetter (1987)
Blacktip	43	880–2000	Males 1300 mm, Females 1550 mm Branstetter (1987a)
Dusky	3	2200–2980	Males 2759 mm, Females 2798 mm Natanson (1995)[1]
Sandbar	48	1060–2437	Males 1800 mm, Females 1803 mm Springer (1960)[2]
Tiger	75	760–3356	Males 2900 mm, Females 2970 mm Clark and von Schmidt (1965)
Nurse	9	1820–3040	Males 2250 mm, Females 2300 mm Compagno (1984)
Sand tiger	3	1800–2199	Males 2200 mm, Females 2200 mm Compagno (1984)
Scalloped hammerhead	17	1010–2882	Males 1800 mm, Females 2500 mm Branstetter (1987b)
Great hammerhead	15	1974–3048	Males 2340 mm, Females 2500 mm Compagno (1984)
Smooth dogfish	13	560–1280	Males 820 mm, Females 900 mm Compagno (1984)
Spiny dogfish	16	600–970	Males 590 mm, Females 700 mm Compagno (1984)

[1] Measurements converted from fork length to total length, TL = FL/0.8396–0.9947 (Kohler et al., 1996).
[2] Measurements converted from inches to mm.

Acknowlegments

For their support or advice for the pilot studies or the manuscript, the authors would like to thank Scott Nichols, Joanne Lyczkowski-Shultz, Warren Stuntz, Arvin Shaw, Butch Pellegrin, Velda Harris, and Perry Thompson of NMFS Mississippi Laboratories; Nancy Kohler, Lisa Natanson, and Wes Pratt of NMFS Narragansett Laboratory; Lee Trent, Enric Cortes, and John Carlson of the NMFS Panama City Laboratory; Michael Bailey of NMFS Silver Spring, Md.; Jose Castro and Cheryl Brown of the NMFS Miami Laboratory; Bob Hueter, Charles Manire, and John Tyminski of the Mote Marine Laboratory; and Steve Branstetter of the Gulf and South Atlantic Fisheries Foundation.

Literature Cited and Selected References

Bigelow, H. B., and W. C. Schroeder. 1948. Fishes of the western North Atlantic. Mem. Sears Found. Mar. Res., Yale Univ., Pt. 1, 576 p.

Bonfil, R. 1994. Overview of world elasmobranch fisheries. FAO Fish. Tech. Paper 341, 119 p.

Branstetter, S. 1987a. Age and growth estimates for blactip, *Carcharhinus limbatus*, and spinner, *C. brevipinna*, sharks from the northwestern Gulf of Mexico. Copeia 1987 (4):964–974.

________ 1987b. Age, growth and reproductive biology of the silky shark, *Carcharhinus falciformis*, and the scalloped hammerhead, *Sphyrna lewini*, from the northwestern Gulf of Mexico. Environ. Biol. Fish. 19(3):161–173.

________ and J. A. Musick. 1994. Comparisons of shark catch rates on longlines using rope/steel (Yankee) and monofilament gangions. Mar. Fish. Rev. 55(3):4–9.

________ and R. Stiles. 1987. Age and growth of the bull shark, *Carcharhinus leucas*, from the northern Gulf of Mexico. Environ. Biol. Fish. 20(3):169–181.

Castro, J. I. 1983. The sharks of North American waters. Tex. A&M Univ. Press, Coll. Sta., 180 p.

________. 1993. The biology of the finetooth shark, *Carcharhinus isodon*. Envir. Biol. Fish. 36:219–232.

Clark, E., and K. von Schmidt. 1965. Sharks of the central Gulf Coast of Florida. Bull. Mar. Sci. 15:13–83.

Compagno, L. J. V. 1984. FAO species catalogue. Vol. 4. Sharks of the world. An annotated and illustrated species catalogue of shark species known to date. Parts 1 and 2. FAO Fish. Synop. 125, vol. 4:1–655.

Kohler, N. E., J. G. Casey, and P. A. Turner. 1996. Length-length and length-weight relationships for 13 shark species from the western North Atlantic. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NE-110, 22 p.

Natanson, L. J., J. G. Casey, and N. Kohler. 1995. Age and growth estimates for the dusky shark, *Carcharhinus obscurus*, in the western North Atlantic Ocean. Fish. Bull. 93:116–126.

NOAA. 1993. Fishery management plan for sharks of the Atlantic Ocean. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., 147 p.

Parsons, G. R. 1985. Growth and age estimates of the Atlantic Sharpnose shark. *Rhizoprionodon terraenovae*: A comparison of techniques. Copeia 1985(1):80–85.

Raschi, W., J. A. Musick, and L. J. V. Compagno. 1982. *Hypoprion bigelowi*, a synonym of *Carcharhinus signatus* (Pisces: Carcharhinidae), with a description of ontogenetic heterodonty in this species and notes on its natural history. Copeia 1982:102–109.

Renaud, M. L. 1986. Hypoxia in Louisiana coastal waters during 1983: implications for fisheries. Fish. Bull. 84:19–26.

Springer, S. 1960. Natural history of the sandbar shark. Fish. Bull. 61(178):1–38.

Untrawlable Bottom in Shrimp Statistical Zones of the Northwest Gulf of Mexico

JASON LINK

Introduction

The shrimping industry in the Gulf of Mexico has criticized the bycatch reduction plans of the Gulf of Mexico Fishery Management Council (GMFMC). A predominant issue the industry has raised is a potential lack of recognition for bycatch reductions that may have already occurred. A specific example of this is that an increase in the untrawlable bottom in shrimping areas could reduce bycatch by the shrimp fishery.

Jason Link was with Johnson Controls World Services—NOAA, NMFS, P.O. Drawer 1207, Pascagoula, MS 39568, and he is currently with the Northeast Fisheries Science Center, NMFS, NOAA, 166 Water St., Woods Hole, MA 02543, jlink@whsun1.wh.whoi.edu.

ABSTRACT—The Gulf of Mexico Fisheries Management Council tasked the National Marine Fisheries Service with determining the extent, if any, of loss of trawlable bottom in the Gulf of Mexico based upon fishing industry concerns. There are approximately 31 million hectares in the 21 shrimp statistical zones in the Gulf, approximately 23 million hectares of waters that are <35 fathoms (where most shrimp trawling effort occurs), and approximately 11 million hectares in zones 10–21, <35 fathoms, which were examined. There are 31,338 known hangs, snags, artificial reefs, hazards to navigation, oil rigs, and similar obstructions which cause trawling to be unfeasible in these zones. There are several refuge (i.e. untrawlable) areas associated with the Alabama Artificial Reefs. Conservatively assuming 1 hectare for each known obstruction, coupled with the known area of each refuge, the estimate of total untrawlable bottom in zones 10–21 less than 35 fathoms in the Gulf is 185,953 hectares, or roughly 1.7% of this total trawlable area. Sensitivity analysis demonstrated the robustness of this assumption, with a range of 0.3–4.3% possible. In specific shrimp zones, untrawlable area is much less than 1% except in zones 10 (26%) and 11 (2.5%), both of which possess a refuge. Other than the implementation periods of these refugia, no temporal trends were detectable with respect to the amount of untrawlable bottom.

Questions of specific concern are: 1) has there been an increase in the amount of untrawlable bottom in the Gulf and 2) if so, when did these changes occur? Thus, the GMFMC asked NOAA's National Marine Fisheries Service (NMFS) to determine the extent, if any, of loss of trawlable bottom in the Gulf based upon shrimp fishing industry concerns.

To address the primary questions raised above, other questions arise. They are: how much area is there in the Gulf Shrimp Statistical Zones (zones); what is the scale of spatial resolution (i.e. amount of change in area) needed to detect a difference within zones; what is the current status of untrawlable bottom in the Gulf zones (specifically, what data sources are there to ascertain this); and what are the temporal trends, if any, and are there data to ascertain this issue?

To assess the bottom condition of the Gulf zones, I assembled data from multiple sources, and then summarized this information by zone to determine the extent of untrawlable phenomena. In addition to addressing the trawlable bottom issue, these data should serve as a baseline for similar fisheries and oceanographic studies.

Materials and Methods

Bottom Area

I used Patella's (1975) estimates for the known amount of area in the Gulf zones (Fig. 1). The total for all zones is 30,901,394.3 ha or, more simply, about 31 million ha. Patella's estimates are commonly available and widely used. Since most shrimp trawling occurs in the shallower portions of these zones, I only assessed bottom area for depths 35 fathoms and shallower, with a Gulf total of 23,431,293 ha, or about 23 million ha.

Zones 1 through 9 were omitted from this analysis. Sparse data at best were available for this region. Relatively little effort has been attempted to assess artificial obstructions in the Florida region, and this is compounded by the underwater topography of this region. Thus, the total area in zones 10–21 in waters less than 35 fathoms is 11,290,485 ha.

Polygonal Areas

There are known areas in the Gulf that are neither amenable, feasible, nor legal for trawling operations. I obtained parameters of these areas (preserves or refugia) to estimate the area that is untrawlable within their bounds. Data collected were simply latitude and longitude corresponding to the corners of these refugia. These were obtained from the following sources.

The Alabama Department of Natural Resources maintains the Artificial Reef General Permit Areas.[1] Although estimated at approximately 900 n.mi.^{2}, after doing the appropriate splitting by zones and removing those portions outside of any zones, the total area from these three areas is slightly greater than 150,000 ha, predominately in zone 10.

The Florida Middle Grounds comprise an area of 153,600 ha, all in zone 6. These coordinates are obtainable

[1] The primary contact is Ralph Havard at 334-861-2882.

from any pertinent navigational chart, but they can be explicitly obtained in Smith et al. (1975). The Florida Keys and Dry Tortugas National Park (NPS and NOS) also comprise assorted polygons, with a combined area of 41,648 ha, predominately in zone 2.[2] However, both of these are only partial estimates of the Florida region. Because I have limited this analysis to zones 10 through 21, these areas were omitted. Also excluded is the Eglin bombing range south of Fort Walton to Panama City, Fla. It is known that trawling is feasible there except during military operations, and it is also beyond the scope of this analysis.

An area purposely omitted from this analysis is the Texas Flower Gardens. Although these areas would qualify, they are all outside (predominately south) of the boundaries of the statistical zones. I assumed that the area associated with these polygons used in this analysis was entirely included in the areas of these zones and shallower than 35 fathoms.

Specific Points

I obtained data to be used as untrawlable point estimates. These data were compiled and source, year, depth, latitude, and longitude (both lat. and long. were in both decimal and minute-degree-second format) were the primary parameters examined. These were obtained from MMS, NOS, GSMFC, ALSG, and TXSG.

The Minerals Management Service (MMS) produced oil rig data on the World Wide Web.[3] This information was downloaded in ASCII format for the analysis.

The National Ocean Service (NOS) produced information on hazards to navigation, commonly known as the AWOIS (NOS, 1994).

The Gulf States Marine Fisheries Commission (GSMFC) produced a listing of artificial reef development in the Gulf (Lukens, 1993).

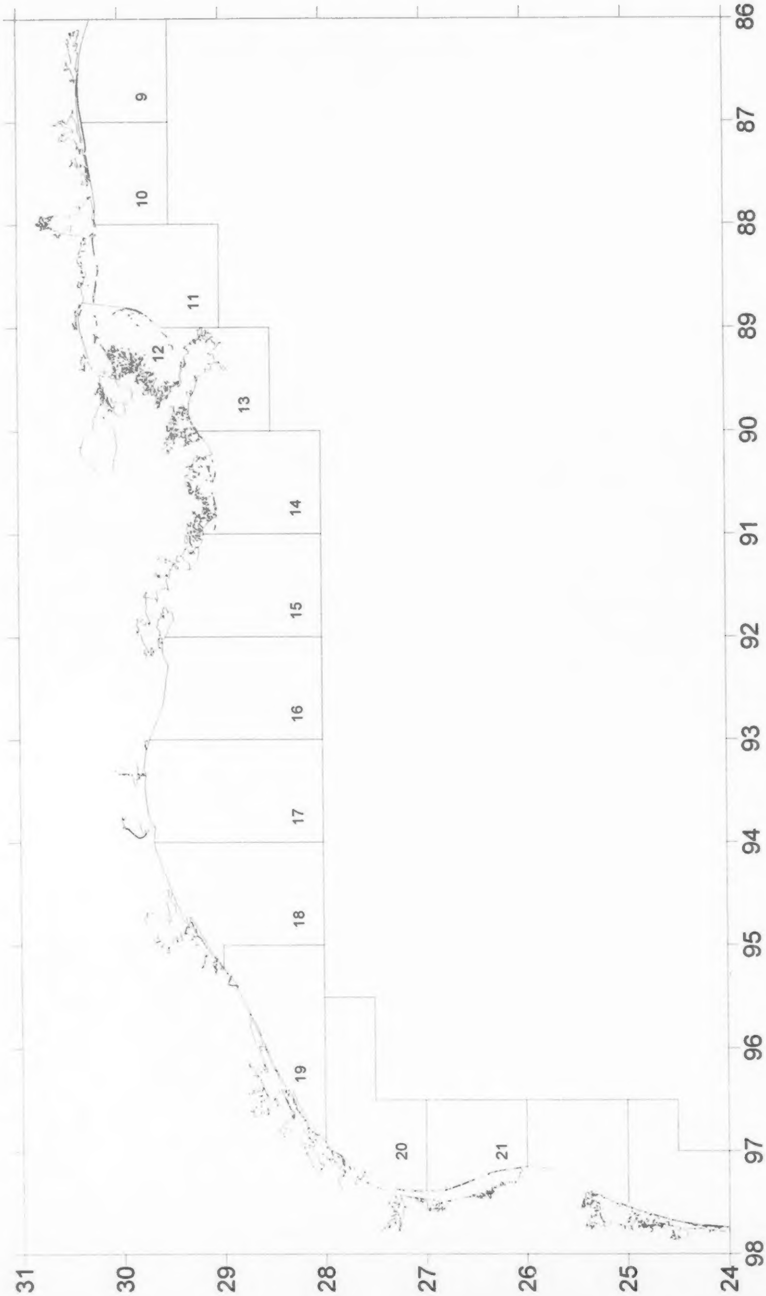


Figure 1.— Shrimp statistical zones in the Northwest Gulf of Mexico.

[2] A contact for this is Ben Haskell at 305-743-2437.

[3] Oct. 1996. http://www.mms.gov/omm/gomr/homepg/pubinfo/freeasci/platform/freeplat.html. A contact for this data is Norman Froomer at 504-736-2782.

Table 1. — Obstructions, polygons, and areas for each (assuming 1 ha per obstruction) by statistical zone relative to trawlable bottom.[1]

Zone	Area (Patella)	Hzd hang (NOS)	Art. reefs (GSMFC)	Hangs (ALSG)	Oil Rigs (MMS)	Hangs (TXSG)	Summary	Area total	Polygons area	Total untrawl.	Trawl. (Patella)	Total untrawable/ trawlable
10	643,145	272	48	86	9		415	415	133,835	134,250	508,896	0.26381
11	915,633	282	29	1,486	241		2,038	2,038	20,118	22,156	893,476	0.02480
12	101,238	57	2	436	26	1	522	522		522	100,716	0.00518
13	324,658	36	3	1,261	324	315	1,939	1,939		1,939	322,719	0.00601
14	791,626	45	3	1,192	602	1,213	3,055	3,055		3,055	788,571	0.00387
15	1,139,186	14	8	1,676	708	1,732	4,138	4,138		4,138	1,135,048	0.00365
16	1,430,383	7	2	2,371	540	1,970	4,890	4,890		4,890	1,425,493	0.00343
17	1,637,564	171	15	1,731	373	1,301	3,591	3,591		3,591	1,633,973	0.00220
18	1,530,259	420	28	1,227	139	1,131	2,945	2,945		2,945	1,527,314	0.00193
19	1,194,823	646	19	1,227	137	1,904	3,933	3,933		3,933	1,190,890	0.00330
20	891,486	603	12	457	66	1,476	2,614	2,614		2,614	888,872	0.00294
21	690,485	55	4	231	7	961	1,258	1,258		1,258	689,227	0.00183
Total	11,290,486	2,608	173	13,381	3,172	12,004	31,338	31,338	153,953	185,291	11,105,195	0.01668

[1] Totals may not add owing to rounding of data

The Alabama Sea Grant Program (ALSG) provided a listing of hangs, snags, and other trawling obstructions (Hosking et al., 1987).

The Texas Sea Grant Program (TXSG) provided an updated listing of similar obstructions (Graham, 1996a, b).

Contacts with state Departments of Natural Resources, Bureaus of Marine Resources, Departments of Conservation, Departments of Wildlife and Fish, and similar institutions revealed only minimal point data (i.e. <100), and these were not explicitly included in the analysis since most were already included in the Sea Grant or GSMFC data sets.

Once all of these data were placed in digital format (ASCII txt and Dbase dbf files), they were debugged and compiled. This compiled data set is housed at the NMFS Mississippi Laboratories facility of the Southeast Fisheries Science Center.[4] The sort procedure in SAS (Statistical Analysis System, v. 6.10) was used to delete all duplicates based upon decimal latitude and longitude coordinates. That is, an obstruction noted from two or more sources to be located at the same place was not counted twice. However, due to slightly different methods of estimating digital latitude and longitude it is possible that there may be some duplication between the two Sea Grant data sets.

Those data (i.e. oil rigs) from the MMS data set known to have been removed were also deleted from further analysis. The total number of rigs from 1990 to 1994 has remained relatively constant (Froomer[5]). During 1983–96, there was an average of about 125 removals per year and an average of about 110 additions per year. This assumes that a site formerly occupied by an oil rig is entirely devoid of bottom obstructions.

After sorting and removals, each obstruction was assigned to the appropriate zone using SAS. I assumed that all of these obstructions were in waters shallower than 35 fathoms.

A conservative assumption is that each of these points represents the center of a circle with an area of 1 ha that is untrawlable. Scanning the hangs, reefs, and similar data sets, I noted the radius of such obstructions (if provided) and none approached that magnitude of area. This assumption is also entirely reasonable for oil rigs (Dyhrkopp[6]). The largest oil rigs in the Gulf are on the order of 300 ft^2, smaller than 1 ha (about 328 ft^2). Conversations with personnel at other agencies (NMFS, Sea Grant, state agencies) affirm this assumption.

Results and Discussion

Untrawlable Bottom

The total area for the refugia is 153,953 ha (Table 1). Without these polygons, <1% (0.3%) of the Gulf in these zones within these depths is untrawlable (Table 2). Accounting for the various removals and duplications, the total number of points from each source were: GSMFC, 173; MMS, 3,172; NOS, 2,608; ALSG, 13,381; and TXSG, 12,004 (Table 1). These obstructions are concentrated in the shelf off Texas and Louisiana from zones 14 to 20. All of these zones examined, except zones 10, 12, and 21, have roughly 2,000 or more obstructions each.

Table 2. — Sensitivity analysis of the area per obstruction relative to the trawlable bottom in zones 10–21 less than 35 fathoms.

Area per point (ha)	Total untrawlable	Total trawlable	Untrawable/ trawlable
Standard (1)	185,291	11,105,194	0.01669
0.1	157,087	11,133,398	0.01411
0.25	161,787	11,128,697	0.01454
0.5	169,622	11,120,863	0.01525
2	216,629	11,073,856	0.01956
4	279,305	11,011,180	0.02537
10	467,333	10,823,152	0.04318
No polygons	31,338	11,259,147	0.00278

Given the assumptions of 1 ha and that all these points are shallower than 35 fathoms, the amount of untrawlable bottom from these point data is estimated at 31,338 ha (Table 1). Sensitivity analysis showed that by assuming each point variably represents 1, 0.1, 0.25, 0.5, 2, 4, or 10 ha, the relative ratio of the changes in these ranges from 1.2 to 4.3% (Table 2). Thus, a robust and reasonable conclusion is that untrawlable bottom tallied from the data sources above constitute about 2% of potential shrimping grounds.

By adding the number of points that are known obstructions, assuming an area for each (in this case, 1 ha), adding this total to the amount of area set aside as refugia, this sum (185,953 ha; Table 1) can be subtracted from the known area of these shrimp zones shallower than 35 fathoms to estimate the

[4] P.O. Drawer 1207, Pascagoula, MS 39568.

[5] Froomer, N. MMS, 1201 Elmwood Park Blvd., New Orleans, LA 70123. Personal commun. Nov. 20, 1996.

[6] Dyhrkopp, F. MMS, 1201 Elmwood Park Blvd., New Orleans, LA 70123. Personal commun. Nov. 20, 1996.

area in zones 10 through 21 that is still trawlable (over 11,300,000 ha). By examining the ratio of total untrawlable bottom to total area, only 1.7% of these zones is untrawlable.

Examining this same ratio by zone unsurprisingly shows that zones 10 (26%) and 11 (2.5%) have a relatively high percentage of their bottoms that are untrawlable. All other zones are much less than 1% untrawlable. The reason the preceding zones have such a high percentage is due to the presence of refugia in these zones. Without these refugia they too would be well below 1% untrawlable.

Changes in Untrawlable Bottom

To address the temporal aspect of this issue, each datum would need an associated year. This information is not available. Simply put, the temporal resolution to address this question does not exist. I could have artificially assigned a year to each obstruction based upon the year the source of each was published, but that did not seem reasonable and is potentially misleading. I examined the data that had known years before and after several cut-off points, and no pattern was observable. Additionally, even if a year was given for when an obstruction was observed, assuming it was placed there in the same year may also not be a reasonable assumption. The predominant type of obstruction expected to change and also amenable to quantification would be oil rigs. Again, conversations with MMS personnel (Froomer[5]) noted the total number of rigs has remained relatively constant, with about 125 removals and 110 additions on average per year during 1983–96.

Given the areas of all Gulf zones, to detect a 1% change in the entire Gulf trawlable bottom, an increase or decrease in 300,000 ha would have to occur Gulfwide. Carried further, a change in 30,000 ha would only be a 0.1% change in the entire Gulf. For areas less than 35 fathoms, 230,000 ha and 23,000 ha would have to be removed to detect a 1% and 0.1% change, respectively. Removing 23,000 ha from all but the smallest zones (12 and 13) produces a 1–4% change within a zone. A change on the order of 23,000 ha would require an interesting and noteworthy event or series of events. Similarly, to observe a 1% change in zones 10 through 21 less than 35 fathoms, 110,000 ha would have to be altered (Table 1).

On an absolute basis, all obstructions should be (and will likely continue to be) tracked and may indeed change. The perception when graphically presenting these data is often extreme and gives an inflated sense of untrawlable bottom due to the scale of representing an obstruction relative to the scale of the map (Fig. 1). However, when weighted by the spatial scale of these zones, at least 110,000 removals or additions would have to occur to detect a 1% change in zones 10 through 21 less than 35 fathoms. This is much greater than the total that have been recorded during the entire period that this information has been tracked.

The implementation periods for the refugia have been the biggest change in trawlable bottom of these zones. Before 1986, zones 10 through 21 less than 35 fathoms had an untrawlable area of 0.27% (Table 2), but after 1989 that rose to 1.67%. Once fully implemented, these reefs added 1.4% to the total untrawlable bottom area in these zones. This largest single change in trawlable bottom is predominately in zone 10. Approximately one-quarter of that zone was untrawlable after these reefs were established. When considered across all zones from 10 to 21 and less than 35 fathoms, the untrawlable area including these refugia is still only 1.7%.

Initial expectations of changes in untrawlable area when this analysis was initiated were on the order of 5–10% of the entire Gulf. The order of magnitude required for this to have occurred seems unlikely. More importantly, this suggests that to detect any change is likely rather difficult due to the spatial scale involved. Thus, although the data do not exist to explicitly ascertain temporal changes in the amount of untrawlable bottom in these Gulf zones, it is highly unlikely that, other than setting aside known areas of extremely substantial size, will there be nor have there been changes in the area that is considered trawlable bottom in the Gulf of Mexico Shrimp Statistical Zones.

Acknowledgments

I thank K. Bryant, M. Bucahanan, F. Dyhrkopp, N. Froomer, D. Hanisko, B. Haskell, R. Havard, A. Jahncke, R. Kasprzak, N. May, M. McDuff, V. Minton, S. Nichols, K. Rademacher, K. Savastano, and R. Wallace for their assistance with this effort.

Literature Cited

Graham, G. L. 1996a. "Hangs" and bottom obstructions of the Texas/Louisiana coast: offshore 10–50 fathoms. Univ. Tex. Sea Grant Rep. TAMU-SG-96-502.

________. 1996b. "Hangs" and bottom obstructions of the Texas/Louisana coast: nearshore 1–12 fathoms. Univ. Tex. Sea. Grant Rep. TAMU-SG-96-501.

Hosking, W., R. K. Wallace, T. A. Lawery, and G. L. Graham. 1987. "Hangs" and bottom obstructions of the north central Gulf of Mexico. Miss-Ala. Sea Grant Rep. MASGC-87-033.

Lukens, R. R. 1993. A profile of artificial reef development in the Gulf of Mexico. GSMFC Tech. Coord. Committ. Rep.

NOS. 1994. User's guide: automated wreck and obstruction information system. U.S. Dep. Commer., NOAA, Natl. Ocean Serv., Silver Spring, Md.

Patella, F. 1975. Water surface area within statistical subareas used in reporting Gulf coast shrimp data. Mar. Fish. Rev. 37(12):22–24.

Smith, G. B., H. M. Austin, S. A. Bortone, R. W. Hastings, and L. H. Ogren. 1975. Fishes of the Florida Middle Ground with comments on ecology and zoogeography. Fla. Dep. Nat. Resourc., Mar. Res. Lab., St. Petersburg, Fla., Fla. Mar. Res. Publ. 9, 14 p.

The index and/or table of contents has been removed and photographed separately within this volume year.

For roll film users, this information for the current volume year is at the beginning of the microfilm. For a prior year volume, this information is at the end of the microfilm.

For microfiche users, the index and/or contents is contained on a separate fiche.

Papers in the *Marine Fisheries Review* 59(1–4), 1997

Errata

Dunn, J. R. 1996. Charles Henry Gilbert (1859-1928), naturalist-in-charge: the 1906 North Pacific expedition of the steamer *Albatross*. Marine Fisheries Review 58(1-2):17-28.

In footnote 8, page 18, the biographical data of Hubert Lyman Clark (1870-1948) was erroneously attributed to Austin Hobart Clark. Correct information on A. H. Clark may be found in Cattell and Cattell (1938). Additionally, the reference in the footnote to Palmer (1948) is in error.

I thank Dr. Gordon Hendler, Natural History Museum of Los Angeles County, Los Angeles, for bringing these errors to my attention. *J. R. Dunn*

Superintendent of Documents **Subscription** Order Form

Order Processing Code:

***5593**

☐ **YES,** enter my subscription(s) as follows:

_____ subscription(s) to ***Marine Fisheries Review*** (MFR),
each at $10.00 U.S. annually

The total cost of my order is $______. Price includes regular shipping and handling and is subject to change. International customers please add 25%.

____
Company or personal name (Please type or print)

____
Additional address/attention line

____
Street address

____
City, State, Zip code

____
Daytime phone including area code

____
Purchase order number (optional)

For privacy protection, check the box below:

❑ Do not make my name available to other mailers

Check method of payment:

❑ Check payable to Superintendent of Documents

❑ GPO Deposit Account ☐☐☐☐☐☐☐ – ☐

❑ VISA ❑ MasterCard

☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

☐☐☐☐ (expiration date)

____
Authorizing signature

Mail To: Superintendent of Documents
P.O. Box 371954, Pittsburgh, PA 15250–7954

Charge your order. It's easy!

MasterCard

VISA

S3S

To fax your orders (202) 512–2250

To phone your orders (202) 512–1800

Thank you for your order!

Editorial Guidelines for the *Marine Fisheries Review*

The *Marine Fisheries Review* publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, the *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Cited

Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, and the year, month, volume, and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8 × 10 inches, sharply focused glossies of strong contrast. Potential cover photos are welcome, but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 50 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

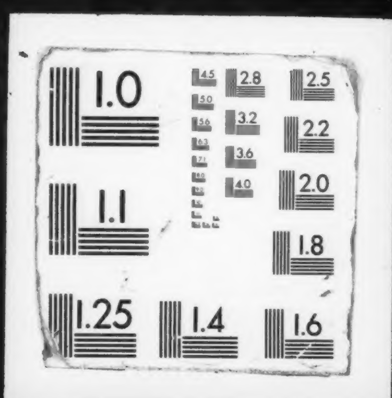
☆ U. S. GOVERNMENT PRINTING OFFICE: 1998 - 689-077/80000

UNITED STATES
DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE
SCIENTIFIC PUBLICATIONS OFFICE
BIN C15700
SEATTLE, WA 98115

OFFICIAL BUSINESS
Penalty for Private Use: $300

Periodicals
Postage and Fees Paid
U.S. Department of Commerce
ISSN 0090-1830

UNIV MICROFILMS INTERNATL M
300 N. ZEEB RD/P.O. BOX 1346
ATT: SER. ACQUISITIONS DEPT
ANN ARBOR, MI 48106-1346


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0